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THE NITROGEN AND MINERAL CONTENTS OF SOME INDIAN COTTONS AND THEIR RELATION TO METHYLENE BLUE ABSORPTION*

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THIS investigation had its origin in the numerous discussions that took place in the past in the meetings of the Indian Central Cotton Committee for preventing the malpractice of mixing inferior cottons with superior types, and the Committee appeared interested in a method to detect such mixtures, so that it could be utilized by law in prohibiting mixing. As the number of possible mixtures in trade was large, the method should be such as to make it possible to detect every type of mixture. Mixing was found to occur between American cottons grown in India and the inferior *desis*. Similarly, mixing was found to take place between improved *desi* cottons with coarse *desi* cottons.

The technological methods in detecting mixtures of inferior and superior varieties of cotton did not prove successful mainly due to the predominant effect of environment on physical properties and consequent variability thus induced. It was, therefore, necessary to look for some method depending on some physical or chemical differences in the lint of different cotton types, though it was expected that similar variations in the chemical constituents may also be induced by environmental factors.

Birtwell, Clibbens and Ridge [1923] were the first to work from that point of view and they found that fully bleached American and Egyptian cottons can be distinguished by the quantity of methylene blue absorbed under standard conditions. This method was not applied to unbleached cotton.

Geake [1924] went a step further and showed that the phosphorus content of lints of different cottons varied and the superior types of cottons such as Sakallaridiz showed less phosphorus content than the inferior types like Indian cottons. The phosphorus content of Egyptian types was on an average 0·09 per cent, of Americans 0·05 per cent and the phosphorus content for Indian cottons varied from 0·054 to 0·124 per cent. He maintained that the mixture of any two of the three types can be determined by the phosphorus content but his claims were not further substantiated. He also found that the phosphorus content of the various types of cotton ran parallel to their methylene blue absorption; though the phosphorus content was determined in raw cotton the methylene blue absorption was measured after

*The work under investigation was carried out under a scheme financed by the Indian Central Cotton Committee.

bleaching. It may be mentioned that figures for methylene blue absorption were taken from the data of Birtwell, Clibbens and Ridge [1923], so no definite conclusions can be reached.

The same author [1924] determined the nitrogen content of lint of different cottons and he found that different varieties of raw cotton can be distinguished by their nitrogen contents. The nitrogen content of Egyptian cottons was in the neighbourhood of 0·3 per cent, while that of American cottons was in the neighbourhood of 0·2 per cent. But the difference observed was not as great as that observed between phosphorus contents, so the method of determining nitrogen content cannot be adopted to the differentiation of varieties.

A qualitative method for the identification of 4F Punjab American cotton and Mollisoni desi cotton in a mixture of the two cottons has been described by Sen [1947]. Gulati [1947] has done quantitative estimation of 4F Punjab American cotton and Mollisoni desi cotton in a mixture of the two, by staining with Victoria blue and differentiating the shade taken by the two cottons. He has claimed to have obtained fairly accurate results, in four unknown samples. It is not, however, stated whether this method was of general application and whether other *desis* and Americans grown in India behaved in the same manner.

Birtwell, Clibbens and Ridge [1925] in another contribution have shown that absorption of methylene blue by bleached cotton of different types of cottons varied and that difference was found to be associated with difference in ash content or more strictly with ash alkalinity. The increase in ash alkalinity increased the absorption of the dye. They also showed that greater the quantity of foreign matter such as proteins and pectic matter present in the lint, greater was the absorption of methylene blue.

On further investigation on the same problem Clibbens and Geake [1926] found that the cottons of Indian origin absorbed 40 to 50 per cent more methylene blue than the American cottons grown in India. They used well scoured cottons in this study. Naturally they found difference in the shade of two samples of bleached cotton belonging to different varieties when they were dyed under identical conditions. Clibbens and Ridge [1925] determined the causes for the differences in the shade observed and they came to the conclusion that this difference between different varieties of cotton was not caused by any difference in the chemical nature of lint of different varieties but was caused by the differences in the fineness of the hair as determined by their hair weight per cm. length. Fine cottons thus gave lighter shade and coarse cottons stained deeper and gave darkest shades.

Similar conclusion was reached by Thomas [1936] and Lawrie [1927].

Sen and Nazir Ahmed [1935-45] undertook an extensive investigation. They did not confine their attention to the shade taken by cotton when placed in a dye but actually measured the quantity of dye absorbed by it. They included twelve varieties of cotton using five substantive dyes of varying molecular weights. Four different treatments were given before their dyeing properties were determined. Their findings are both conclusive and interesting. They showed that there was very

little difference in percentage absorption between cotton to cotton and the dye absorption per unit length increased as the fibre weight per unit length increased. The shade of the dyed cotton was deeper in the case of coarse cottons and lighter in the case of fine cottons as the absorption of dye per unit length was more in coarse cotton and less in the fine cotton.

While studying the staining properties of lint of Mollisoni desi cotton and 4F Punjab American cotton in the laboratory of Cotton Physiological Scheme, Dr. Samant found that when these cottons were stained in Leishman's stain and examined under the microscope, the fibres of 4F Punjab American cotton stained red and the majority of fibres of Mollisoni desi cotton stained blue. There were, however, few fibres of *desi* cotton that stained red purple like the 4F Punjab American cotton. Instead of finding out the causes of this difference in the staining properties of different fibres, work was directed to utilize this difference for detecting mixtures of the two cottons. Red stained fibres of *desi* cottons can only be seen under the microscope, but when *desi* lint stained in this stain was seen with the naked eye it appeared blue, as the red stained fibres being few in number were entirely covered up with blue stained fibres. So the blue stained fibres of *Mollisoni desi* cotton can be readily distinguished.

Mixtures of 4F American and Mollisoni were obtained from various sources and stained with a mixture of these two stains. After washing, the blue-stained lumps of *desi* cotton can be readily differentiated from the red purple stained American lint. Though the method gave very encouraging results to begin with exceptions began to appear as the scope of the investigation was widened to include other finer types of American and *desi* cottons. With the partition of the country, the main problem of mixing now in India was connected with the mixing of improved *desi* cottons with coarse and inferior *desi* cottons. This method was not found effective in detecting mixtures of the improved and coarse Indian cottons. The colour difference was not marked so as to differentiate a mixture from a pure type. So the work on this problem remained at this stage.

The theoretical aspect of this finding has not been followed up. The American cottons when placed in this stain absorbed more of the red dye while the *desi* absorbed more of the blue dye during the first 20 minutes. It was also not known as to what happened when the cotton was kept longer especially for 18 hours which was the period determined for the maximum absorption of methylene blue.

Investigation

The above review of the literature shows that some work has been done to correlate methylene blue absorption of cotton with its chemical or physical properties. Among the chemical properties the phosphorus content and the nitrogen content were determined by Geake [1924].

It is possible that some other mineral that enters into the composition of fibre may be playing some role on the quantity of methylene blue absorbed by it. A complete mineral analysis of lint of Indain cottons was,therefore,considered necessary.

It would be interesting to study the mineral composition of the different cottons grown in India and to see how far they differ from one another. In spite of the negative evidence so far obtained, it is possible that the staining properties and mineral composition may be in some way interrelated.

The investigation would be incomplete if the total ash content and ash alkalinity of different cottons grown in India are not determined side by side. Fargher and Probert [1925] determined the ash content and ash alkalinity of cottons grown in different parts of the world and found that these two properties were interrelated. For *desi* Indian cottons the mean ash content was 1·28 per cent and the mean ash alkalinity 19·2 and for American cotton grown in India these were 1·25 and 18·6 per cent respectively.

Various workers mentioned above have shown that the quantity of methylene blue absorbed was dependent upon the fibre weight per unit length. No attempt has, however, been made before to determine the relationship between methylene blue absorption and the fibre diameter and this has been done in this investigation.

So far, the chemical analysis of lint has been restricted to the determination of potash, phosphate and nitrogen. This is not adequate as it gives no idea of the total amount of basic and acidic radicals that enter into the composition of lint. The cotton plant absorbs large quantities of sulphates and chlorides as shown by Dastur and Ahad [1946] from the soil. It would be interesting to find out if these ions are also present in the lint.

The Mollisoni desi cotton stained deep blue and the American cotton stained reddish-purple when placed in a mixture of alcoholic solution of methylene blue and eosin-A for twenty minutes while finer and coarser varieties of *desi* cottons did not show any difference when stained. The causes of this difference need, therefore, to be determined.

Davidson [1950] in his detailed investigation on the acidic properties of the cotton cellulose used mixture of dyes one of which was methylene blue and the others were either astraphloxine, isoquinoline red, or pseudocyanine. A comparison of the affinities of the two basic dyes was made by a study of the concurrent absorption of the two dyes from a mixture of the two.

A study of the results obtained by him indicated that absorption of the two dyes from a mixture was unequal at different concentrations of the two dyes, used in the mixture. The main object of his investigation was to measure the affinities of cations of a number of basic dyes for the carboxyl groups of acidic oxy-celluloses and he found that they differed widely in affinity.

In the experimental studies carried so far, the absorbing medium is swollen cellulose, and in a dyeing process, a part of the dye exists as the cellulose and a part as the free dye in the pores. The diameter of the pores may vary in the cellulose from cotton to cotton and thus the amount of diffusion of the dye may also vary. Similarly, it is also possible that purified cellulose (unscoured) which has not been subjected to treatment with oxidizing agents may behave as possessing a very

small carboxyl content. The exchange of basic ions of methylene blue salt occurs with the acidic groups of the cellulose, i.e. the mass of dye per unit volume will be equal to the concentration of absorbed dye and the concentration of the free dye in the aqueous medium filling the pores. If the carboxyl content and the diameter of the fibres vary from cotton to cotton, the total dye absorption would also vary as will be shown in the investigation described below, that there is a difference in the absorption of methylene blue in the cellulose of different cottons.

Methods of Analysis

All the lint was thoroughly mixed and divided into a large number of parts. Some portion from each small heap was taken out and mixed to form the representative sample. The samples so prepared were carefully combed and the adhering dust and other foreign particles removed. These carefully prepared samples were used in all the different types of analysis mentioned in this investigation.

Ash percentage, ash alkalinity, nitrogen and other minerals were determined by known standard methods. Methylene blue was estimated by the A. O. A. C. method [1938] and repeated trials revealed that the presence of eosin-A did not interfere with its estimation.

Colorimetric method was employed for the determination of methylene blue absorption from a pure solution of methylene blue. Standard solutions of the dye were prepared for comparison of methylene blue alone.

Chemical analysis for ash contents, alkalinity of different cottons and methylene blue absorption was made on the same sample.

It may be pointed out that the ash contents (amount of mineral matter) have been determined by Davies and Dreyfus [1889], Monie [1904], Mitechel and Prideaux [1910], but these determinations were apparently made on samples which were contaminated by dust and sand, and, therefore, the values given by them for the ash contents of the same type of cottons varied widely. This defect was removed by Fargher and Probert [1925] who combed the samples before analysis and removed all foreign matter. The same precaution was taken in this investigation. Even though the samples appeared clean, extra care was taken to remove dust particles.

Relation of Ash Content and the Ash Alkalinity with the Three Species of Cotton

(*a*) Arboreum *cottons*

The ash content and ash alkalinity of the different stains of *arboreum* cottons grown in different parts of India are given in Table I(*a*). The ash content was found to vary from 1·15 per cent to 1·37 per cent, the mean ash content being 1·258 per cent. These results are not in close agreement with those given by Fargher

and Probert [1925]. Though their results pertained to Indian cottons, their values varied from 1·1 to 1·6 per cent, as they evidently included Indian *herbaceum* cottons obtained from Surat and Broach (Gujrat) also. Except for the samples of *arboreum* cottons obtained from the Punjab, Madhya Pradesh, Madhya Bharat and Saurashtra, the ash content of these cottons was about 1·1 per cent.

The ash alkalinity figures given in Table I (*a*) indicate a variation from 15·9 to 18·8. Only the Bani cotton from Hyderabad Deccan gave a low ash alkalinity while the values for ash alkalinity varied within narrow limit for the remaining strains of *arboreum* cottons grown in India. When the ash alkalinity per gram of ash was calculated the values obtained were lower and varied from 12·3 per cent to 16·0. Gaorani cotton showed the highest ash alkalinity per gram of ash while *Mollisoni*, Mathio and Bani cottons gave the lowest values.

(*b*) Harbaceum *cottons*

The ash content and ash alkalinity for different strains of *herbaceum* cottons are given in Table I(*b*). The ash contents of these cottons were consistently higher than those of *arboreum* cottons irrespective of localities. The values for ash content varied from 1·1 per cent to 1·8 per cent. Except in the case of Mungari cotton from Raichur and Hagari-1 from Bellary district, the lint of *herbaceum* cottons appeared to contain more mineral matter than the lint of *arboreum* cottons. The mean ash content of *herbaceum* cotton has come out to be 1·502 per cent and it was found to be significantly higher than the mean ash content of coarse *arboreum* cottons.

The greater the ash content, the greater has been found to be the ash alkalinity which has fluctuated from 15·75 to 25·5. The mean ash alkalinity of these cottons was found to be 20·185 and it was found to be significantly higher than the mean ash alkalinity of *arboreum* cottons.

The mean ash alkalinity per gram of ash in *herbaceum* cottons was, however, lower than the mean ash alkalinity per gram of ash in *arboreum* cotton, on account of higher ash contents of the former.

(*c*) Hirsutum *cottons*

The ash content and ash alkalinity of American cottons grown in India and Pakistan are given in Table I(*c*). These values were of the same order and showed similar variations as discussed above for *herbaceum* cottons. Both the ash content and ash alkalinity with the exception of Perso-American cotton from Uttar Pradesh were as high as the ash content and ash alkalinity of *herbaceum* cottons. The mean ash content for these cottons was 1·541 per cent and mean ash alkalinity was 20·100.

It was clear that the lint of *arboreum* cottons differed markedly in its chemical properties from the lint of *herbaceum* or *hirsutum* cottons as there was a distinct and significant difference in their ash content and the total ash alkalinity. The main

difference was in the ash content as the values of ash alkalinity per gram of ash did not differ in these three types of cottons. The Indian cottons as such did not have less ash content than the cottons grown in America, as reported by previous workers. Only the *arboreum* cottons grown in India possessed this characteristic. The *herbaceum* cottons grown in India which can also be classified as Indian cottons showed the same ash content as the American cottons grown in India or elsewhere. Thus the difference was a specific one and not caused by locality.

The statistical analysis given in Table II showed that in both the characters viz. ash content and the total ash alkalinity the mean square for species was significantly higher than that for the varieties within species. This was due to the fact that *arboreum* cottons differed significantly from the other two species.

TABLE I (*a*)

The ash content and ash alkalinity of the three species of cotton grown in different parts of India

(Arboreums)

Name of variety	Ash per cent	Total ash alkalinity	Ash alkalinity per gm. of ash
Mollisoni	1·398	17·758	12·70
Sind N. R.	1·180	17·128	14·51
Gaorani 6	1·176	18·835	16·00
Bani	1·150	15·920	13·84
Gaorani 6 E/3	1·209	17·902	14·80
Gaorani 12 F/2	1·222	18·542	15·15
Verum 434	1·188	16·792	14·13
H 420	1·200	18·370	15·31
Jarilla	1·364	18·746	13·74
Malvi 9	1·378	17·924	13·01
Mathio	1·374	16·956	12·34
Mean	1·258	17·716	14·14

TABLE I (*b*)

(Herbaceums)

Locality	Name of variety	Ash per cent	Total ash alkalinity	Ash alkalinity per gm. of ash
Hyderabad Deccan	Kumta	1·419	19·416	13·68
Do.	Kumta	1·397	16·549	11·84
Do.	Mungari	1·086	15·754	14·50
South India	Hagari I	1·168	17·154	14·68
Do.	Sal. 69	1·444	19·261	13·33
Dharwar Area	Jayawant	1·685	22·342	13·25
Gujarat	1027 A.L.F.	1·801	25·502	14·15
Do.	Suyog (1949-50)	1·602	20·481	12·78
Do.	Suyog (1944-45)	1·590	23·239	14·61
Do.	Type 1-4 (1949-50)	1·676	21·798	13·00
Do.	Type 1-4 (1944-45)	1·653	20·543	12·42
	Mean	1·502	29·185	13·48

TABLE I(*c*)

(Hirsutums)

Locality	Name of variety	Ash per cent	Total ash alkalinity	Ash alkalinity per gm. of ash
Punjab (W)	289 F/43	1·672	22·048	13·19
Do.	289 F/K25	1·650	22·024	13·34
Do.	4 F	1·600	19·870	13·24
Do.	L. S. S.	1·458	21·650	14·84
Sind	Sind Sudhar	1·556	19·363	12·44
Do.	M_4	1·508	20·148	13·36
Madhya Pradesh	Buri 107	1·668	20·712	12·41
Dharwar (Karnatak)	Gadag I	1·619	20·400	12·60
Deccan	Parbhani American	1·462	18·087	12·37
Uttar Pradesh	Perso American	1·259	16·737	13·29
South India	Combodia ($C0_2$)	1·595	20·063	12·57
	Mean	1·541	20·100	13·06

TABLE II

Analysis of variance in ash per cent and ash alkalinity

Mean values for three species	Ash per cent	Ash alkalinity
1. *Arboreums*	1·258	17·716
2. *Herbaceums*	1·502	20·185
3. *Hirsutums*	1·541	20·100

Variance due to	Ash per cent		Ash alkalinity M.Sq.
	d.f.	M.Sq.	
Between species	2	0·2588**	20·7974**
Arboreum vs. others	1	0·5081**	41·5945**
Between *hirsutum* and *harbaceum*	1	0·0081	0·0002
Between varieties within species	30	0·0248	4·1944

**Significant

THE CORRELATION BETWEEN ASH CONTENT AND ASH ALKALINITY

Fargher and Probert [1925] found that the ash content and ash alkalinity were inter-related. As a large number of these determinations on Indian cottons have been made, correlation coefficients between ash content and ash alkalinity were worked out. For *arboreum* varieties, the correlation coefficient was 0·1733 which was not significant. This was due to small variations in ash percentage and corresponding small variations in ash alkalinity. The correlation coefficient for *herbaceum* varieties was +0·8905 and was significant at 1 per cent P level, for *hirsutum* varieties it was +0·8501 significant at 1 per cent P level.

THE MINERAL CONTENTS OF THE LINT OF DIFFERENT COTTONS GROWN IN INDIA

The mineral analysis of the lint of the Indian cottons has been reported by Mathews [1924] in his book on textile fibres, but varieties taken are very few. The different mineral contents of lint of different cottons growing in different tracts were, therefore, determined to study their variation from cotton to cotton and tract to tract.

Nitrogen

The results of nitrogen content of lint of the different strains of cotton belonging to three species are given in Table III. The values of percentage nitrogen have fluctuated from 0·192 to 0·308 : L.S.S. and Hagari-1 have given lowest nitrogen content while Indore-1 has given the highest nitrogen content. These values are not different from those given by Ridge [1924] for Indian cottons. There is, however, no constant difference between the nitrogen contents of cottons belonging to three species. American cottons showed similar fluctuations in the nitrogen contents

as the coarse *arboreum* cottons. The nitrogen contents of cottons obtained from south (Hagari 1 and Combodia) have given the lowest nitrogen contents. The same remarks apply to cottons obtained from the Punjab (Mollisoni and L.S.S.).

Potash

The potash content has fluctuated between 0·3 per cent to 0·5 per cent. A study of the results given for all the different elements indicates that potash enters into the composition of lint in the largest proportion. When the results are calculated as percentage of the total ash content, more than 30 per cent of the ash consists of potash.

There is again no consistent difference in the potash content of lint of cottons belonging to three species. The potash contents of the coarser *arboreum* cottons are of the same order as the potash contents of the *hirsutum* cottons. The mean potash content of five strains of *arboreum* cottons is 0·454 while that of the four *hirsutum* cottons has come out to be 0·466. The mean potash content of the three *herbaceum* cottons is 0·481 (Table V).

The Gaorani cottons and the L.S.S. have given the lowest values for potash (Table III) while Indore-1 and Hagari-1 have given the highest values.

TABLE III

The percentages of nitrogen and different minerals on 100 gm. of lint

Variety	Total nitrogen	K_2O	CaO	Fe_2O_3	Mgo	Total basic radicals
Mollisoni	0·233	0·438	0·154	0·0228	0·044	0·653
Gaorani-6	0·222	0·361	0·172	0·0185	0·047	0·598
Verum-434	0·266	0·469	0·142	0·0200	0·055	0·686
H-420	0·242	0·527	0·183	0·0243	0·051	0·785
Malwa-9	0·264	0·477	0·175	0·0314	0·052	0·735
Hagari-1	0·199	0·536	0·181	0·0300	0·054	0·801
Suyog	0·235	0·444	0·165	0·9171	0·050	0·676
Jayawant	0·265	0·463	0·171	0·0300	0·042	0·706
L.S.S.	0·192	0·375	0·183	0·0228	0·040	0·621
Dharwar American	0·253	0·453	0·184	0·0257	0·049	0·712
Indore-1	0·308	0·538	0·271	0·0342	0·057	0·900
Combodia (CO_4)	0·211	0·498	0·158	0·0243	0·054	0·734

When the results are studied tractwise, no conclusions can be reached except that the values of percentage of potash are lower for Gaorani-6 in Hyderabad State and L.S.S. in the Punjab.

The Verum-434 cotton obtained from Madhya Pradesh showed the least quantity of potash in the ash, viz. 29·38 per cent, while H, 420 obtained from the same area showed higher quantity of potash in the ash, viz. 37·11 per cent.

Jayawant cotton from Karnatak showed the highest quantity of potash, viz. 40·05 per cent in the ash.

Lime

The results of lime content given in Table III show that the lime contents of lints of different cottons did not vary widely. It varied from 0·15 to 0·18 per cent except for Indore-1 where the value was 0·271 per cent (it may be remarked that the ash content of Indore-1 was very high). There were also no specific differences in the lime contents except that the mean lime content of *hirsutum* cottons was slightly higher than that of the other two species of cotton. The difference was too small to be of any significance.

Lime forms about 10 to 15 per cent of the ash of the lint. The percentage of lime in the ash of *hirsutum* cottons appeared to be slightly high. Whether this was really so, can be only determined by analysing a large number of samples of these cottons. The ash of Verum-434 contains, like potash, the lowest quantity of lime, viz. 8·86 per cent. Thus this cotton was different from the rest so far as its composition of ash was concerned.

Magnesium

The magnesium content of lint has fluctuated within narrow limits. It varied from 0·04 to 0·05 per cent. Thus it is present in very small amounts in the lint. There are no differences in the magnesium contents of the lint of the three groups of cotton. There are also no differences in the magnesium content of lint of cotton grown in different tracts.

Iron

Iron is present in a very small proportion in the cotton lint. The concentration of iron as Fe_2O_3 varied from 0·0171 to 0·0342. Indore-1 showed the highest iron content whereas Suyog showed the lowest quantity.

The mean iron content for the five *arboreum* cottons was 0·023, for *herbaceum* cottons 0·026 and for *hirsutums* 0·027.

Iron as Fe_2O_3 forms 1·1 to 2·6 per cent of the lint ash. The maximum percentage of iron was found in the ash of Jayawant cotton and minimum in Suyog.

Phosphoric acid

Geake [1924] found that the phosphorus content of lint of Indian cottons was highest, i.e. 0·12 per cent, though a study of the figures given by him showed that

there were Indian cottons like the Omras and the Bengals which had lower phosphorus content than the Egyptian and American cottons. The results given in Table IV for phosphorus contents show that in the lint of cottons grown in different parts of India the phosphorus content varied from 0·044 per cent to 0·144 per cent. Jayawant, Dharwar American and Malvi-9 were characterised with low phosphorus content while Verum-434, H-420, Hagari-1 and Gaorani-6 with very high phosphorus content. In the figures given by Geake [1924] the phosphorus content was found to fluctuate from 0·05 per cent to 0·124 per cent. Thus the results obtained agreed with those obtained by Geake [1924].

TABLE IV

The percentages of different acidic radicals on 100 gm. of lint

Variety	P_2O_5	SO_4	CL_2	Total acidic radicals
Mollisoni	0·060	0·322	0·140	0·522
Gaorani-6	0·106	0·281	0·157	0·544
Verum-434	0·132	0·290	0·113	0·535
H-420	0·118	0·320	0·136	0·574
Malvi-9	0·050	0·328	0·129	0·507
Hagari-1	0·144	0·380	0·139	0·663
Suyog	0·085	0·478	0·124	0·687
Jayawant	0·044	0·415	0·145	0·604
L.S.S.	0·092	0·376	0·103	0·571
Dharwar American	0·051	0·380	0·147	0·578
Indore-I	0·096	0·392	0·154	0·642
Combodia (CO_4)	0·066	0·350	0·130	0·546

There appeared to be a good difference between the means of the phosphorus contents of *arboreum* cotton and *herbaceum* cottons on one side and the *hirsutum* cottons on the other. The mean phosphorus content was 0·093 per cent for *arboreums*, 0·091 per cent for *herbaceums* and 0·076 per cent for *hirsutums*. (Table V.) Thus these results also confirmed the results obtained by Geake [1923].

Phosphorus forms 3 to 8 per cent of the ash. The maximum percentage of phosphorus in ash was found in Gaorani-6, Verum-434, H-420 and L.S.S., while minimum amounts were found in Malvi-9, Jayawant and Dharwar American.

Sulphur

Next to potash, sulphur enters into the composition of the lint in the largest quantity as given in Table IV. This is a remarkable result as so far no such finding has been reported. From the point of view of the chemistry of lint this is an important finding though its significance is at present not understood. In fact, what part all these minerals play in the properties of the fibre is not known. Sulphur content varied from cotton to cotton. It is found to vary from 0·28 per cent to 0·478 per cent. Suvog cotton from Surat was found to contain exceptionally high quantity of sulphur whereas Gaorani-6 the lowest amount. In all the three *herbaceum* cottons this element was found in large quantities. The mean sulphur content of *herbaceum* cotton was found to be 0·42 per cent while for *arboreums* and *hirsutums* it was found to be 0·31 per cent and 0·37 per cent respectively.

Sulphur as sulphate formed 23 to 36 per cent of the ash content. Thus it entered into the composition of ash in the largest amount next to potash.

The percentages of all minerals in the lint were not found to be in the same order as the percentages of the same mineral in ash. Thus the percentage composition of each mineral in the lint differed from the percentage comopsition of each mineral in the ash of lint.

It is possible that suplhur enters into the lint composition to neutralize the high potash and lime content as phosphates appear to enter into very small amounts.

Chlorides

Chlorides are found to be present in the composition of lint in a greater proportion than even phosphates as shown in Table IV. The concentration varied from 0·10 to 0·15 per cent. Thus its concentration did not vary much from cotton to cotton. The mean chloride content for the three species of cotton was found to be nearly the same, viz. 0·13 per cent.

In the Karnatak cottons, phosphate content was found to be lowest, while the sulphate and chloride contents appeared to be very high, otherwise there was no indication of any difference between the tracts.

Chlorine as chlorides formed about 10 per cent of the composition of the lint ash. Thus on the percentages of the ash basis the chlorides are found to be in greater proportion than phosphates.

In order to compare the mineral and nitrogen contents of the lint of the three species of cotton, the means for different strains for each species of cotton were calculated and they are given in Table V. There appeared to be no difference between the nitrogen, potash, and chloride contents of the lint of the three species of cotton, while lime content was found to be distinctly higher in *hirsutum* cottons than in case of the other two species of cotton.

TABLE V

The means of nitrogen and other minerals in the lint of different species of cotton

Species	Percentage N_2	Percentage K_2O	Percentage CaO	Percentage MgO	Percentage Fe_2O_3	Percentage P_2O_5	Percentage SG_4	Percentage Cl_2
Arboreums	0·245	0·454	0·165	0·050	0·023	0·093	0·31	0·13
Herbaceums	0·232	0·481	0·172	0·048	0·026	0·091	0·42	0·13
Hirsutums	0·243	0·466	0·199	0·050	0·027	0·076	0·37	0·13

The phosphate content on the other hand was lower in American than in the other two cottons, while sulphur content was higher in the *herbaceum* cottons than in the cottons belonging to *arboreum* or *hirsutum* groups. Thus, this investigation has confirmed the findings of the previous worker Geake [1924] that phosphorus content of the American cotton was generally lower than that of Indian cottons, with some exceptions like Mollisoni and Jayawant which belong to *arboreum* and *herbaceum* groups.

This investigation has also brought to light another difference between American and Indian cottons in their lime contents. This lime content of the former types were generally higher than the lime contents of Indian cotton belonging to the two species. The presence of a very high percentage of sulphur in the lint was another important finding. The *herbaceum* cottons showed the highest percentage of sulphur in the lint.

Statistical test for significance for these differences in the mineral contents of the lint of the three species of cotton could not be applied as the number of cottons, analysed for each species, was small.

THE METHYLENE BLUE ABSORPTION BY INDIAN COTTONS

The quantity of methylene blue absorbed by the twelve Indian cottons belonging to three different species was measured according to the method already described. This was done with a view to determine (1) if there was any relation between methylene blue absorption and the chemical properties such as ash content, ash alkalinity or any one of the minerals, (2) if there was any relation between physical properties such as fibre weight or the fibre diameter and the quantity of methylene blue absorbed, and (3) to find out an explanation for the observed fact that when Mollisoni desi cotton and an American cotton like 4F or the L.S.S. were stained in an alchoholic solution of a mixture of two dyes, viz. methylene blue and eosin-A for 20 minutes, the former was stained blue and the latter stained red-purple.

The quantity of methylene blue absorbed by each variety of cotton from an aqueous solution of the pure dye is given in the following table (Table VI). The results are expressed in gm. per 100 gm. of lint in 18 hours.

TABLE VI

Quantity of methylene blue absorbed from an aqueous solution by 100 gm. of cotton in 18 hours

Arboreum		*Herbaceum*		*Hirsutum*	
Mollisoni	1·63	Hagari-1	1·56	L.S.S.	1·12
Gaorani-6	1·12	Suyog	1·52	Dharwar American	1·36
Verum-434	1·48	Jaywant	1·38	Indore-1	0·92
H-420	1·40			Combodia (CO_4)	
Malvi-9	1·14				1·10
Mean	1·35		1·49		1·12

Mollisoni cotton absorbed the largest quantity of methylene blue among the cottons studied. There were, however, *arboreum* cottons like Gaorani-6 and Malvi-9 which absorbed smaller quantity of methylene blue like the American cottons.

If the means of the quantities of methylene blue absorbed are considered for the three species, the *hirsutum* cottons were found to absorb less methylene blue than either the *herbaceums* or the *arboreums*. No generalization, however, was possible as exceptions occured in both.

It is reported that coarse cottons absorb more methylene blue than finer types. This conclusion is also not supported by the results obtained, as Malvi-9 is known to be a coarse cotton and its methylene blue absorption is low.

It is possible that this difference in the absorption of methylene blue from cotton to cotton may be due to difference either in the diameter of the pores or the carboxyl groups in the cellulose molecule.

THE RELATION OF ASH CONTENT AND ASH ALKALINITY WITH METHYLENE BLUE ABSORPTION

It was reported by Birtwell, Clibbens and Ridge [1925] that high ash alkalinity of bleached cotton was associated with a high absorption of methylene blue. This was not found to be the case in this investigation. Neither was there any relation between ash content and the methylene blue absorption.

Side by side ratio of methylene blue absorbed to ash alkalinity was determined. The ratios diversed widely indicating that methylene blue absorbed by a cotton was not proportional either to the ash content or the ash alkalinity.

The correlation coefficients between methylene blue absorption and ash content and between methylene blue absorption and ash alkalinity were worked out and they were found to be negative and insignificant. Thus the conclusion of Birtwell. Clibbens and Ridge [1925] for bleached cottons do not hold good for raw cottons.

TABLE VII

Correlation coefficient between methylene blue absorption and ash content and ash alkalinity

	Ash content	Ash alkalinity
Methylene blue absorption	—0·0187	—0·2128

RELATION BETWEEN METHYLENE BLUE ABSORPTION AND OTHER ELEMENTS IN THE LINT

It was reported by Geake [1921] that there was some relation between methylene blue absorption by bleached cotton and the phosphorus content of the same unbleached or raw cotton. It was, therefore, considered of interest to study the relationship between methylene blue absorption with the different minerals determined in the lint.

There appeared to be no relation between methylene blue absorption and any mineral including phosphate. The values of ratios for each mineral are widely diverged. The results obtained are complex and it is evident that the mineral content of the lint bore no relation to the absorption of methylene blue by different cottons which appears to be purely a physical phenomenon.

The correlation coefficients between methylene blue absorption and each mineral content were also worked out as given in Table VIII.

TABLE VIII

Correlation coefficients for methylene blue absorbed and each mineral contents

Element	Coefficient	Element	Coefficient
K	+0·007	P_2O_5	+0·1614
Ca	—0·5815	SO_4	+0·1019
Mg	—0·1523	Cl_2	—1·1340
Fe	—0·3505	N_2	—0·2302

The values of correlation coefficients for all minerals are not significant except in the case of calcium where the correlation coefficient between calcium and methylene blue absorption has come out significant and negative. The high correlation co-efficient was only due to high calcium content of Indore-I. Excluding Indore-I the correlation coefficient is not significant.

Correlation between Methylene Blue Absorption and Fibre Weight and Fibre Diameter

Sen and Nazir Ahmed [1944] from their investigation concluded that the dye absorption increased as the fibre weight increased. The shade of the dyed cotton was, therefore, deeper in the case of coarse cotton and lighter in the case of the fine cotton.

The fibre weight of each of the twelve cottons was determined according to the method mentioned before. The sample of material was taken from the same material that was used for the determination of methylene blue absorption. It was also undertaken to determine fibre diameter as well as to see if there was any better correlation between fibre diameter and methylene blue absorption, than fibre weight and methylene blue absorption. These results are given in Table IX.

Table IX

Methylene blue absorption, fibre weight and fibre diameter

Variety	Fibre weight 10·6 oz./per inch	Fibre diameter 10·3 inch	Methylene blue absorbed in gm. per 100 gm. of lint
Mollisoni	0·288	1·110	1·63
Gaorani-6	0·158	0·915	1·12
Verum-434	0·153	0·910	1·48
H-420	0·172	0·965	1·40
Malvi-9	0·164	0·955	1·14
Hagari-I	0·170	1·055	1·56
Suyog	0·201	1·037	1·52
Jayawant	0·166	0·988	1·38
L. S. S.	0·143	0·915	1·12
Dharwar American	0·163	0·964	1·36
Indore-I	0·102	0·886	0·92
Combodia (CO_4)	0·108	0·875	1·10

It is evident from the figures given in Table IX that wherever the methylene blue absorption was high the fibre weight and fibre diameter were also high and those cottons which absorbed the least quantity of methylene blue the fibre weight as well as the fibre diameter for them were also lowest. There was, however, not so close relationship between their physical properties and methylene blue absorption in the intermediate cases between two extremes. Correlation coefficients between fibre weight and methylene blue absorption and fibre diameter and methylene blue absorption were determined for the estimations of the dye absorption made with a pure solution of the dye as well as in a mixture of methylene blue and eosin-A.

The correlation coefficients between methylene blue absorption and fibre weight and fibre diameter are given in Table X.

TABLE X

Correlation coefficients between methylene blue absorption and fibre weight and fibre diameter

	Fibre weight	Fibre diameter
Methylene blue absorption from a mixture of methylene blue and eosin-A.	+0·7432	+0·7770
Methylene blue absorption from a pure solution.	+0·7684	+0·8243

From Table X it will be seen that in both cases there was a significant correlation between fibre weight as well as fibre diameter and methylene blue absorption. The values for correlation coefficients were higher in the case of fibre diameter than in the case of fibre weight. In both the sets the values for the correlation coefficients were higher in case of the dye absorption made from a pure solution of methylene blue than with the mixture of two dyes.

It is clear that the quantity of dye taken up by cellulose depends upon its absorption surface. Generally, the coarse cottons provide larger surface than fine cottons, though there are coarse cottons like Malvi-9 and Gaorani-6 which have low methylene blue absorption and low fibre weight and fibre diameter.

ABSORPTION OF METHYLENE BLUE FROM AN ALCOHOLIC SOLUTION OF METHYLENE BLUE AND EOSIN-A

It was pointed out in the introduction that when Mollisoni *desi* cotton (*arboreum*) and 4F American cotton were stained for twenty minutes in an alcoholic solution of methylene blue and eosin-A, Mollisoni cotton after washing with distilled water for an hour turned blue while the 4F Punjab American cotton after similar treatment stained reddish purple. It appeared later that this did not hold good for all *desi* cottons though the American cottons as a rule stained reddish purple.

Mixtures of coarse *desi* and improved fine *desi* cottons could not be differentiated. The *arboreum* and *herbaceum* which are both Indian *desi* cottons could also not be distinguished.

It was, therefore, necessary to investigate this phenomenon as to why some *desi* cottons stained markedly blue and all American cottons markedly red when put for twenty minutes in the mixture of methylene blue and eosin-A. Apparently *desi* cottons absorbed more of methylene blue while the American cottons absorbed more of eosin during the first twenty minutes. Thus *desis* took up a basic dye while Americans took up an acidic dye in greater proportion from a mixture of the two dyes in equal proportions.

It was undertaken to determine the total quantity of methylene blue absorbed in 20 minutes and in 18 hours from a mixture of methylene blue and eosin-A, according to the method mentioned before.

The results of the quantity of methylene blue absorbed in 20 minutes and 18 hours by different cottons are given in Table XI.

TABLE XI

Quantity of methylene blue in gm. absorbed from a mixture of methylene blue and eosin in 20 minutes and 18 hours per 100 gm. of lint

Variety	Absorption in		Percentage of the total quantity absorbed in 20 minutes
	20 minutes	18 hours	
Mollisoni	0·848	1·554	54·71
Gaorani-6	0·649	1·080	60·09
Verum-434	0·702	1·376	51·24
H-420	0·748	1·398	53·43
Malvi-9	0·580	0·954	61·05
Hagari-I	0·724	1·420	50·99
Suyog	0·829	1·478	55·64
Jayawant	0·750	1·310	57·25
L. S. S.	0·540	0·880	61·36
Dharwar American	0·620	1·248	49·60
Indore-I	0·600	0·810	74·00
Combodia (CO_4)	0·680	1·020	66·60

A study of the results showed that the rate of absorption of methylene blue varied from cotton to cotton as even the quantity absorbed in the first 20 minutes was different in different cottons.

The percentage of the methylene blue absorbed in 20 minutes of the total absorption in 18 hours is not constant for different cottons.

Mollisoni, Suyog and Hagari-I absorbed the largest amounts of methylene blue in the first 20 minutes as well as in 18 hours, whereas Indore-I, Dharwar American and L. S. S. absorbed the least amounts. Malvi 9 is also a *desi* cotton which absorbed smaller quantities like the American cottons.

A comparison of the results given in Table VI and XI would show that the presence of eosin-A in methylene blue solution did not in any way alter the quantities of methylene blue absorbed in 18 hours. There were only small differences between the quantities of methylene blue absorbed by these cottons from a pure aqueous solution of methylene blue and from a mixture of the two dyes. That may be due to slight differences in the lint of the same cotton.

An examination of lint of each cotton after it had remained in the mixture of two dyes for 18 hours showed that all cottons stained blue though there were differences in the tinges of blue of each cotton. But none of the American cottons showed reddish purple colour as was the case when these cottons were stained in the mixture of the two dyes for only 20 minutes. Thus it was evident that differences observed in the stains taken up by these cottons were found only when they were stained for 20 minutes in the mixture of the two dyes.

Progressive Absorption of Methylene Blue from the Mixture of the Two Dyes

It was necessary to find out at what stage all cottons get stained blue with methylene blue dye even though there may be differences in tinge or shade of the stained cotton. In 20 minutes the American cotton generally gets stained purple on account of lesser absorption of methylene blue dye and simultaneous absorption of eosin-A. It was necessary to find out whether by keeping the lint for more than 20 minutes in the mixture the differences in the shade taken up by different cottons diminish or increase. These determinations would also reveal at what period after immersion of the lint the absorption of methylene blue is complete.

The results obtained indicated that after five hours there was practically no increase in the absorption of methylene blue. Whatever small differences were found were negligible as such differences will be noticed even in two sets stained separately for 18 hours.

It was also found that the maximum absorption occurs in the first twenty minutes after which the quantity absorbed diminished so much so that after one hour the quantity absorbed was very small.

An examination of the lint of different varieties indicated that 20 minutes immersion in the mixture of stains was the optimum period for giving maximum differentiation between the tinge and shades taken by different cottons.

It can now be understood, why this method of staining the lint of American and *desi* varieties of cotton in a mixture of two dyes, cannot be successful. There is no consistent difference in the quantities of methylene blue absorbed between all *desi* varieties on the one hand and all American varieties on the other hand. It appears that lint is stained definitely blue after a certain amount of absorption of the dye occurs. Below that quantity, the stain taken up appears purple on account of absorption of eosin-A. Thus Mollisoni *desi* cotton would be stained blue as it has absorbed the largest quantity of methylene blue while L.S.S. which has absorbed the least quantity of methylene blue would take a purple stain in the first 20 minutes. This difference raised a false hope that all *desi* cottons would behave like Mollisoni. This was, however, not found to be the case and the results of the quantities of dyes absorbed would explain the failure of this method. Malvi-9 which is known to be a coarse *desi* cotton, absorbed as much quantity of methylene blue as the American and L.S.S. cottons. Similarly, Gaorani-6 which is a fine *desi* cotton, absorbed nearly as much methylene blue as Combodia cotton, which belongs to American group. As the shade taken up by a cotton depends upon the quantity of the dye absorbed, it is expected that American and *desi* cottons absorbing the same amount of dye would not be differentiated.

Absorption of Methylene Blue by Scoured Cottons from a Mixture of Two Dyes and Methylene Blue alone

The differences in the absorption of methylene blue, either from a pure solution of the dye or a mixture of two dyes, between different cottons, it may be argued, are due to differences in the foreign matter contents present in them. Greater absorption by Mollisoni *desi* cotton of methylene blue may be due to its foreign matter content. It was, therefore, necessary to determine finally this point by determining the dye absorption of different cottons after treatment with alkali and subsequent washing with distilled water to make them free from alkali. The foreign matter may consist of fatty acids, waxes and proteinous substances.

It has been shown by Sen and Nazir Ahmad [1944] that alkali boiled cottons absorb lesser amount of dyes than the untreated cottons. It was, therefore, necessary to determine if the same differences in the methylene blue absorption and the shades of cotton persist between different cottons even after scouring treatment.

In the first instance the lint was treated with 1 per cent sodium carbonate and washed with distilled water. The material was soaked in 1 per cent sodium carbonate for two hours. It was then washed with 50 cc. of distilled water 10 times till free from sodium carbonate.

Table XII gives results of the quantities of methylene blue absorbed from a mixture of two dyes and from pure solution of methylene blue.

TABLE XII

Methylene blue absorption from a mixture of dyes and pure methylene blue solution by different cottons after alkali (1 per cent Na_2CO_3) treatment in gm. per 100 gm. of lint

Variety	Absorption from mixture in		Absorption from pure solution in 18 hours
	20 minutes	18 hours	
Mollisoni	0·66	1·32	1·38
Gaorani-6	0·51	0·97	1·01
Verum-434	0·52	1·18	1·25
H-420	0·55	1·20	1·28
Malvi-9	0·45	0·86	1·01
Hagari-1	0·55	1·20	1·28
Suyog	0·68	1·27	1·36
Jayawant	0·57	1·15	1·23
L. S. S.	0·41	0·80	0·92
Dharwar American	0·49	1·11	1·18
Indore-I	0·49	0·81	0·85
Cambodia (Co_4)	0·53	0·90	1·04

The results showed that methylene blue absorption by each cotton decreased on account of alkali treatment, but the difference in the quantities of dye absorbed by different cottons still persisted and the order of quantity absorbed by each cotton remained the same.

Another set of samples of cotton were boiled with 2 per cent caustic soda for one hour and washed free of alkali. Methylene blue absorption was then determined as before. Mixture of methylene blue with eosin-A and methylene blue pure were used.

The results obtained indicated that though the quantity absorbed by each cotton, after treatment with caustic soda for one hour, was found to be further reduced, the difference in the amount absorbed by different cottons still remained showing that the presence of foreign matter in the lint was not producing these differences.

CONCLUSIONS

A study of the relation between physical and chemical properties of the lint of various cottons and their relation to methylene blue absorption was undertaken as it was found in the laboratory that some *desi* cottons belonging to *arboreum* and

herbaceum groups and American cottons belonging to *hirsutum* group showed differences in colour when stained with a mixture of two dyes, one basic and one acidic, *viz.*, methylene blue and eosin-A in equal proportions (0·5 per cent solution of each dye).

The study of the ash content and the total ash alkalinity revealed that the cottons of *arboreum* group were characterised with a lower ash content and ash alkalinity than the cottons beloging to *herbaceum* and *hirsutum* groups.

Statistical analysis of the results of ash content showed that *arboreum* cottons differed significantly from the other two species of cottons.

As the ash content in the *arboreum* cottons was generally low, the total ash alkalinity was also low as both were closely interrelated.

A higher lime content in the lint of the American cottons than in the lint of Indian cottons was another finding of this investigation.

The lint of all cottons showed a very high sulphur content. The *herbaceum* cottons showed the highest sulphur content.

The absorption of methylene blue by the lint of twelve different cottons was determined and it was found that on the whole fine American cottons absorbed less quantity of methylene blue than the Indian cotton (*arboreum* and *herbaceum*). There were, however, exceptions where Indian cottons like Gaorani-6 and Malvi-9 absorbed lesser quantities, while Dharwar American cotton absorbed larger quantities than the normal. The mean quantity of this dye absorbed by *arboreum* was 1·35 per cent, by *herbaceum* 1·49 per cent, and by *hirsutum* 1·12 per cent in 18 hours.

A study of the values of ash content and ash alkalinity and the quantity of methylene blue absorbed did not indicate any relationship between them.

When the results of ash alkalinity were expressed as per gm. of ash, there appeared to be no significant difference between the ash alkalinity of the lint of the three groups of cotton.

Similarly there was no relationship between the phosphate content and methylene blue absorption as first reported by Geake [1923] for bleached cottons. There was no relationship between any of the minerals and the methylene blue absorption except lime, which was found to be negatively correlated with methylene blue absorption. The correlation coefficient came out significant at 5 per cent level. This significant correlationship was obtained on account of high calcium content of Indore-I, which had a very low value for methylene blue absorption. If Indore-I was omitted from the calculations for correlation coefficient, the value of the coefficient became low and non-significant.

The study of the fibre weight and the fibre diameter revealed that both the fibre diameter and fibre weight were highly correlated to dye absorption. The correlation coefficient between fibre weight and the dye absorbed was 0·7684** and that between fibre diameter and the dye absorbed was 0·8243*. Thus there was still better correlation between fibre diameter and the dye absorbed.

Thus, the dye absorption mainly depended on the physical property of lint and there was no indication of any effect of the chemical property of the lint on the dye absorption.

It was found that methylene blue absorption by each cotton either in 20 minutes or in 18 hours was not much affected by the presence of another dye as the quantities of dye absorbed were nearly the same from a pure solution of methylene blue or the mixture of two dyes either after 20 minutes or 18 hours. The quantities of methylene blue absorbed by different cottons showed wide differences. Mollisoni, Hagari, and Suyog cottons absorbed much more dye than L.S.S., Malvi-9, and Combodia, both in 20 minutes and 18 hours. The absorption of eosin-A by different cotton, on the other hand, was much less and was nearly the same in all cottons from an alcoholic solution in 20 minutes. Thus those cottons which absorbed larger amounts of methylene blue, the methylene blue colour predominated and they stained definitely blue. Blue tinge predominates after a certain quantity of methylene blue is absorbed and the eosin-A colour is masked. Those cottons which absorbed lesser quantities of methylene blue in the first 20 minutes consequently attained bluish purple tinge. But this difference between the shades and tinge in different strains did not appear to be specific as some *desi* cottons absorbed very small amounts of methylene blue while some American cottons absorbed larger amount of the same dye in 20 minutes and this method which appeared first promising of detecting mixtures of American and *desi* cotton could not be successfully employed for all cottons.

The differences in the absorption of methylene blue dye by different cottons were also not produced by the differences in the foreign matter content as alkali-boiled lint even showed the same differences in the quantities of the dye absorbed.

Summary

It was undertaken to study the nitrogen and mineral contents and ash alkalinity and ash content of different Indian cottons belonging to three species, *viz.*, *G. arboreum* *G. herbaceum* and *G. hirsutum* grown in different tracts and to determine if there was any relation between any chemical property and methylene blue absorption.

The ash content and total ash alkalinity of cottons belonging to *arboreum* group was significantly lower than those of *herbaceum* or *hirsutum* group, even though they were all grown in India. Thus it was a specific difference.

There was no relationship between ash alkalinity or ash constituents and methylene blue absorption.

Generally, some *desi* cottons absorbed more methylene blue than the American cotton, but there were exception like Malvi-9 and Dharwar American.

Methylene blue absorption was found to be unaffected whether it was pure solution or a mixture of methylene blue and eosin-A.

A majority of *arboreum* and *herbaceum* cottons absorbed larger amounts of methylene blue than a majority of American cotton, from a mixture of methylene blue and eosin-A in twenty minutes. Similarly there were differences in the quantities of methylene blue absorbed either by *arboreum*, *herbaceum* or *hirsutum* cottons. Thus cottons took up different shades of blue or bluish purple. The Mollisoni *desi* cotton absorbed largest amount of methylene blue, while L. S. S. and Indore-I (Americans) absorbed the least amount from a mixture in twenty minutes, while eosin-A absorption was nearly the same. Thus Mollisoni stained blue while L.S.S. stained purple. But this difference did not hold good for some Americans or some *desis*. Thus the method of detecting mixtures of Americans with *desi* cottons could not be of general applications.

The above conclusions hold good when lint is immersed for 20 minutes. If the cottons are kept longer in the mixture they all take up different shades of blue.

The differences in the absorption of methylene blue by different cottons are not due to differences in the foreign matter present in the lint as the scoured or alkali treated cottons behave in the same way.

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GROWTH AND PHYSICO-CHEMICAL PROPERTIES OF SUGARCANE SAP AS AFFECTED BY DEFICIENCIES OF NITROGEN, PHOSPHORUS AND POTASSIUM

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(With 3 Text-Figures)

SUGARCANE showed considerable variation in growth and composition when nitrogen, phosphorus and potassium were withheld. Thus nitrogen deficiency caused yellow green colour of foliage, premature death and browning of tips and margins of older leaves, poor elongation of primary stalk, light red colour of stem with greater length and smaller diameter of roots. Retardation of vegetative growth and poor accumulation of carbohydrates were also evident [Martin, 1934]. Leaf growth and moisture content were particularly affected [Clements *et al.* 1941] in young leaves more than in old [Arrhenius, 1928]. Typical effects of nitrogen were also presented by Singh [1942] and Lal and Prasad [1948]. During juvenile stage withholding of nitrogen supply reduced intake of elements and checked the development of assimilating system. In adolescence, all vegetative characters were poorly developed. During presenescene partial deficiency proved helpful on sucrose and juice purity. It was considered that nitrogen absorbed from partially deficient cultures was entirely utilized for metabolic activities, while that absorbed in larger quantities from excessive nitrogen cultures remained in a state of luxury consumption [Lal, 1951]. It was further made evident that absence of nitrogen markedly lowered nitrogen content, and reduced intensity of nutrition and moisture content. Sulphur and ash content, on the contrary, were richer in nitrogen deficient sugarcane [De, 1952]. Marked reduction in amide, amino acids and insoluble nitrogen fractions were recorded but the sequence of metabolic changes leading to protein formation was not much affected by nitrogen deficiency. Nitrogen deficiency also improved glucose, fructose and total reducing sugars of leaves but their concentration in root and stem were less affected. Photosynthesis of deficient plants was reduced, while respiration was supernormal at 90 and 225 days and subnormal at 135 and 180 days. The average life cycle response of nitrogen deficiency on respiration, however, remained normal (Lal *et al.* 1950).

Phosphorus also affected growth in many ways. Its deficiency lowered height and leaf number [Lal and Srivastava, 1949]. Narrow leaves, slender stalks, short internodes, tip drying of old leaves and infection with *Pythium* root rot resulted in poor growth of phosphorus deficient canes. Its absence interfered with the

translocation of carbohydrates and caused accumulation of sugars and soluble nitrogen compounds [Martin, 1934]. As against these abnormalities, potassium deficiency caused abnormal distribution of vessels, cortex and parenchyma cells [Hartt, 1929]. Depression of growth, leaf discolouration, die back of leaf tip and development of red midrib were also indicated [Hartt, 1934]. Stalks were found to taper, and tops assumed a fan like appearance ; heavy infection of *Pythium* root rot, poor formation of proteins and carbohydrates were also characteristically noted.

A critical examination of these effects showed that little was known about the effects of these deficiencies on physico-chemical properties of sugarcane sap. The present investigation aimed at providing some information on growth and density, surface tension, viscosity, osmotic pressure, solute concentration, *p*H, electrical potential, electrical resistance, specific electrical conductivity of sap, bound and free water and moisture percentage of sugarcane shoot as affected by these mineral deficiencies.

Material and Method

Layout plan

Sugarcane variety Co. 453 was grown under four distinct conditions of nutrition with the help of Hoagland's complete nutrient and deficiency solutions. The details of the cultures were as follows :

1. Variety	Co. 453
2. Pot size	12 in.×18 in.
3. Quantity of sand	30 kg. per pot
4. Time of sowing	21—2—1952
5. Time of transplanting one bud germinated setts	4—3—1952
6. Treatments	(*a*) Complete nutrition (*b*) N—deficiency (*c*) P—deficiency (*d*) K—deficiency
7. Total number of cultures	4×10=40

The experiment in short involved the determination of the effects of four nutritional deficiencies on growth and physico-chemical properties of sugarcane.

Characters studied

Measurements of height, number of shoots, leaf number, leaf area, girth of main cane stem, number of millable canes and fresh weight of component parts were taken at two stages of 100 and 190 days after planting. The recorded data were statistically analysed to assess the effects of these deficiencies.

Physico-chemical properties of sap were also studied at the two sampling stages of 100 and 190 days. At the first stage of 100 days, separate determination of physico-chemical properties were made on the extracted sap from the green leaf and the stem. Statistical analysis of the effect of two plant parts, two samples and four conditions of nutrition on each property was done. At the second stage of 190 days, however, the composite stem sample was used for the estimation of various physicochemical properties of sap.

The procedure of extraction of sap has already been described earlier [Mehrotra, 1950]. The extracted sap was cooled to a temperature of 21°C and used in requisite quantity for the estimation of density, surface tension, viscosity, *p*H, electrical potential, electrical resistance, specific electrical conductivity and osmotic pressure of the sap. The procedure for these determinations was the same as described in previous paper [Lal and Tandon, 1955].

The concentration of total soluble solutes in the sap was determined by the formula $\frac{P \times W}{22{\cdot}4}$ where P=the osmotic pressure; W=gm. of water per gm. dry weight of the material; and 22·4 was the osmotic pressure of molecules of undissociated solute in 1,000 gm. of water under normal conditions. The solute concentration thus obtained was expressed as number of gram molecular weights of the solute per kg. of dry plant material.

For bound and free water content of tissues, a 150 gm. sample of green leaves was collected from different treatments in the morning, wrapped in a moist towel and brought to laboratory. 10 gm. of this material was used for the determination of moisture percentage. Another 20 gm. sample was employed for free water determinations. The procedure of estimating free water, in general, was similar to that indicated by Meyer [1929], Sayre [1932], Loomis and Shull [1937] and Mehrotra [1950]. Quantity of total water and free water in the sample being known, the amount of bound water was determined as indicated earlier [Mehrotra, 1950]. Bound water was generally expressed as percentage of total water unless otherwise indicated. Ratio of bound/free water × 100 was also calculated.

Experimental Findings

Growth characters and physico-chemical properties of sugarcane as affected by mineral deficiencies

Mineral deficiencies had a significant effect on all the growth characters. The stage of growth and the interaction between mineral deficiencies and stages, showed significant effects on height, leaf area and weight of millable canes and leaves. Root weight was also significantly affected by stage of growth.

Analysis of mineral deficiency effects on sap characteristics of leaf and stem showed highly significant effect on all the physico-chemical properties excepting surface tension, moisture content and bound and free water. So far as plant parts were concerned, significant effects were only recorded on density, osmotic pressure, specific electrical conductivity, electric potential of sap and moisture content of the tissues. The effect of mineral deficiencies and plant part interaction was equally significant on all characters excepting surface tension. It, therefore, appeared beyond doubt that deficiencies of nitrogen, phosphorus and potassium besides affecting external growth attributes, had a more deep seated effect on the plant sap as well.

Analysis of composite sap from sugarcane grown under different conditions of mineral deficiencies, revealed the highly significant effect of these deficiencies on density, surface tension, viscosity, osmotic pressure, solute concentration, electrical resistance, specific electrical conductivity, *p*H, and electric potential of the extracted sap. Moisture content and the percentages of free and bound water or the ratio between bound and free water did not vary significantly under these conditions. The effect of stage of growth was equally significant on all these physico-chemical properties excepting density and percentages and ratios of bound and free water. Interaction between mineral deficiencies and stages of growth showed an equally marked effect on all these physico-chemical properties of sap.

Effect of mineral deficiencies on growth characters

Nitrogen deficiency reduced the number of tillers and leaves, height of the shoot, leaf area and weight of leaves and canes. Phosphorus deficiency showed no significant effect on number of tillers in comparison to the complete nutrition cultures but appeared poorer in this respect from canes raised under potassium deficiency. It had a more depressing effect than potassium deficiency which showed no significant variation from the complete nutrient canes. Height of shoot was depressed by potassium deficiency but phosphorus deficiency showed no significant variations. Leaf area was on the contrary, reduced both under potassium and phosphorus deficiencies; the reductions were less in case of potassium than under phosphorus deficiency. Weight of the canes was, however, more, reduced under complete nutrient cultures. Leaf weight was also reduced under phosphorus deficiency as compared to potassium [Fig. 1]. Age effects were significant on height, leaf area, cane weight and leaf weight but no significant response on shoot and leaf-number were recorded.

Effect of plant part and mineral deficiency on physico-chemical properties

Density of the sap was highest under complete nutrition and was significantly lowered under mineral deficiencies in the decreasing order —N>—K>—P. Stem sap showed a relatively higher density than leaf sap [Fig. 2]. Surface tension of the sap was highest under phosphorus deficiency and was significantly superior to the surface tension of sap under nitrogen deficiency. Plants raised under —N, —K

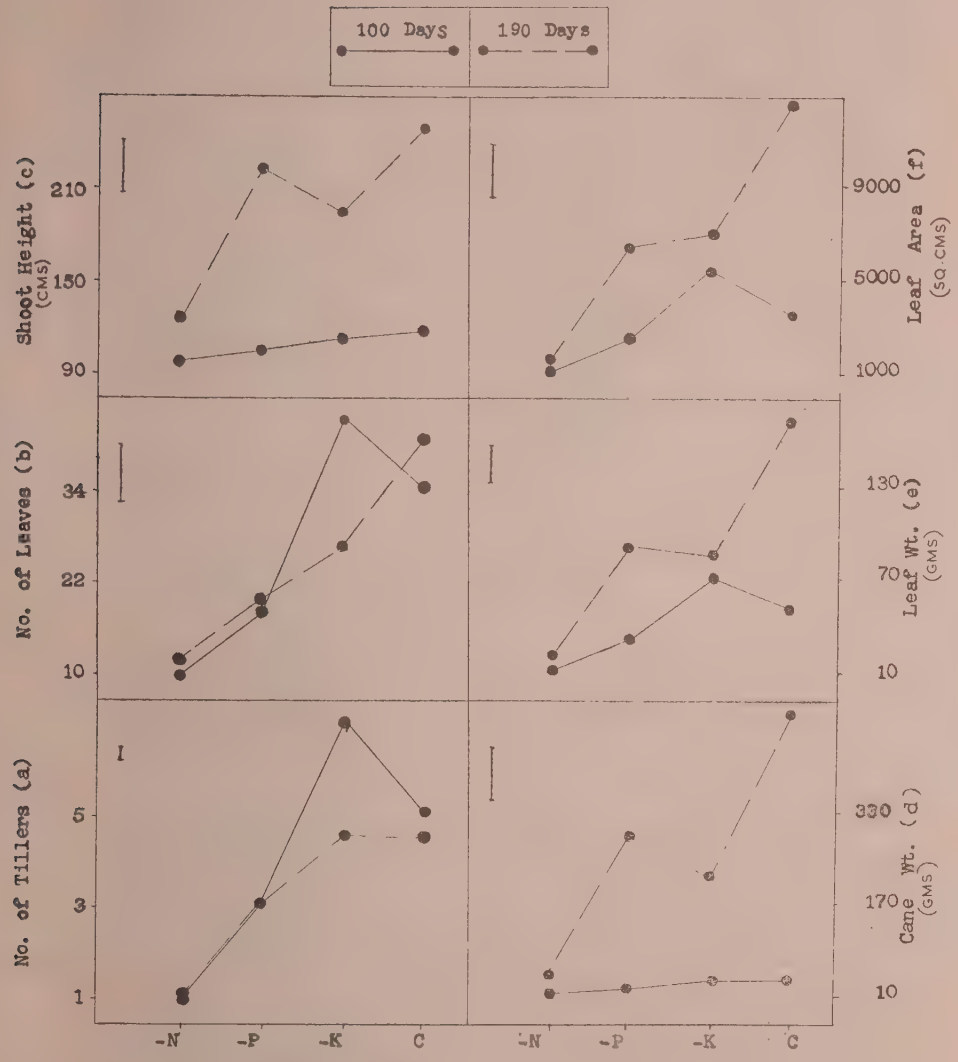

FIG. 1. Effect of mineral deficiencies on growth characters of sugarcane

and complete nutrient conditions showed no significant variations in surface tension at all, irrespective of whether the sap was extracted from the leaf or the stem.

Viscosity of sap under conditions of complete nutrition was significantly higher than the viscosity recorded under nitrogen and phosphorus deficiencies, but potassium showed no significant effect. Similarly variations due to leaf and stem samples were equally insignificant on the viscosity of the sap [Fig. 2].

Of all the cultures, high osmotic pressure was recorded under nitrogen deficiency and was reduced under phosphorus and potassium deficiencies. The latter two showed no significant differences amongst themselves. Leaf sap was higher in osmotic pressure than the stem sap excepting under conditions of nitrogen deficiency, where the reverse was the case [Fig. 2].

Solute concentration (gram molecules per kg. of plant dry material) was highest under conditions of complete nutrition and was significantly lowered under all deficiencies. Nitrogen deficient cultures were poorest in this regard, while potassium and phosphorus deficiencies though slightly better never attained the values recorded for the control. The stem was usually richer in solutes than the leaf in all the cultures [Fig. 2].

Electrical resistance of the sap was highest under phosphorus deficiency followed by complete nutrition, nitrogen deficiency and potassium deficiency. Sap from the stem invariably showed higher electrical resistance than from the leaf [Fig. 2].

Specific electrical conductivity was also highest under phosphorus deficiency and was lowered under —N, —K and complete nutrition. Differences between —P, and control and —K were statistically significant. Leaves in general, showed a higher specific electrical conductivity than the stem [Fig. 2].

Deficiency of nitrogen showed the highest pH of the sap than that recorded under —P,—K and total nutrition. Differences between the latter three were not significant at all. The leaf sap at an average was slightly more acidic as compared to the stem sap under all deficiencies though the reverse happened to the case under complete nutrition [Fig. 2].

No significant variation in electrical potential of sap was noted in —P, —K or complete nutrition canes. Deficiency of nitrogen lowered this property markedly below that recorded for the above three treatments. The leaf tissue at an average showed a potential of 113·125 milli-volts as against the stem which showed a potential of 108·250 milli-volts. A downward gradient of decreasing potential from the leaf to the stem was recorded under all deficiencies : the reverse was the case under complete nutrition. Here the gradient showed an upward trend of decreasing electrical potential from the stem to the leaf [Fig. 2].

The stem also showed a higher percentage of total moisture as compared to the leaf. Barring nitrogen deficiency which reduced moisture content, differences due to — P or —K were not at all significant when compared to the control [Fig. 2].

Free water content on the other hand, showed no significant variation under different deficiencies. Similarly leaf and stem portions also failed to indicate any

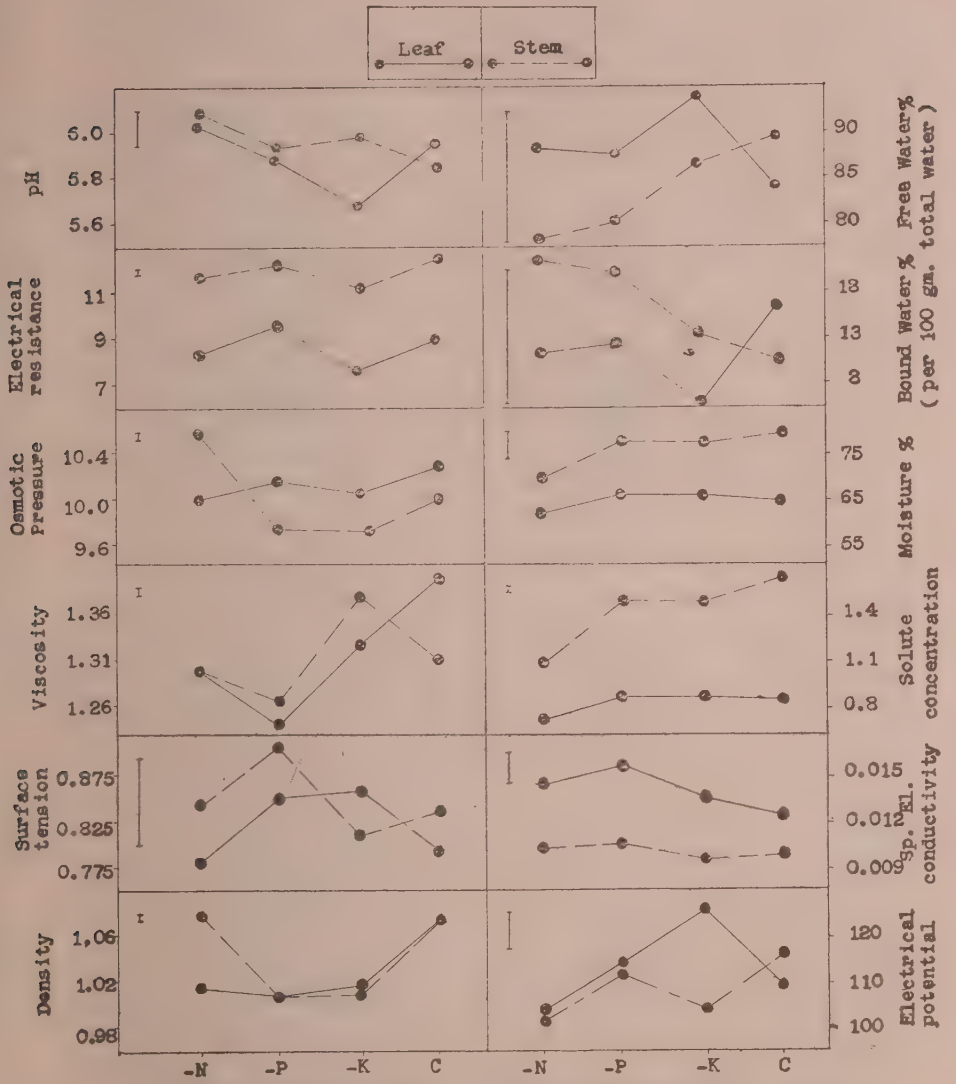

FIG. 2. Effect of mineral deficiencies on physico-chemical properties of sugarcane

1. Solute concentration .. .. .. gm. mol./kg. of dry material.
2. Osmotic pressure .. Atmos.
3. Electric potential .. milli volts.
4. Electrical resistance. Ohms.
5. Sp. elect. conductivity .... Mhos.

significant variations in free water content. Bound water was relatively low under —K but showed no significant difference from other treatments. Variations due to plant parts were also insignificant [Fig. 2].

Bound/free water ratio also showed markedly low values under potassium deficiency in leaf and stem as compared to the deficiencies of nitrogen and phosphorus. On an average this ratio was relatively low under potassium deficiency. Statistical examination, however, revealed that the differences between various treatments were generally insignificant. When expressed as percentage of dry weight, free water content was found to be significantly high in stem as compared to the leaf. The effect of mineral deficiencies was found to be insignificant. Bound water per 100 gm. dry matter was lower in potassium deficiency and was relatively higher under conditions of nitrogen and phosphorus deficiencies. The extent of reduction in bound water under potassium deficiency or improvements recorded under nitrogen and phosphorus deficiencies, however, failed to reach the level of significance. This was equally true for the bound/free water ratio expressed on dry matter basis of plant parts. Potassium deficiency apparently lowered this ratio most in leaf, while in stem all deficiencies tended to improve this ratio slightly above that of the control. The reduction or improvement recorded, however, were not statistically significant.

Effect of plant age and mineral deficiencies on physico-chemical properties of sap

Comparative effects of mineral deficiencies on various physico-chemical properties were also analysed at two stages of sugarcane growth. These effects conclusively showed that density, viscosity and electrical resistance were highest in canes raised under complete nutrition. Phosphorus deficiency on the other hand, increased surface tension, specific electrical conductivity, electrical potential and percentages of total and free water in the tissue. Nitrogen deficiency increased osmotic pressure *p*H and bound water percentage more than other deficiencies. Potassium deficiency increased solute concentration most [Fig. 3].

Besides the improvements in physico-chemical characteristics noted above, deficiencies of mineral ingredients lowered some of the properties of sap as well. Relatively, phosphorus deficiency lowered density, viscosity, osmotic pressure, solute concentration, electrical resistance, *p*H and bound water more than other mineral deficiencies. Absence of potassium lowered surface tension and specific conductivity to a minimum, while nitrogen deficiency reduced electric potential and free and total moisture content more than other deficiencies. Some of these effects were highly significant, indicating once again that physico-chemical properties were markedly affected by the conditions of nutrition under which the sugarcane grew [Fig. 3].

It was also significant to note that improvement in surface tension, osmotic pressure, solute concentration, electrical resistance, electrical potential and moisture content were noted with advance in age of the plant. Viscosity, specific conductivity and *p*H were, on the contrary, significantly lowered as age advanced [Fig. 3]. Age of the plant was, therefore, as potent a factor in altering the physico-chemical properties of the sap as the mineral deficiency.

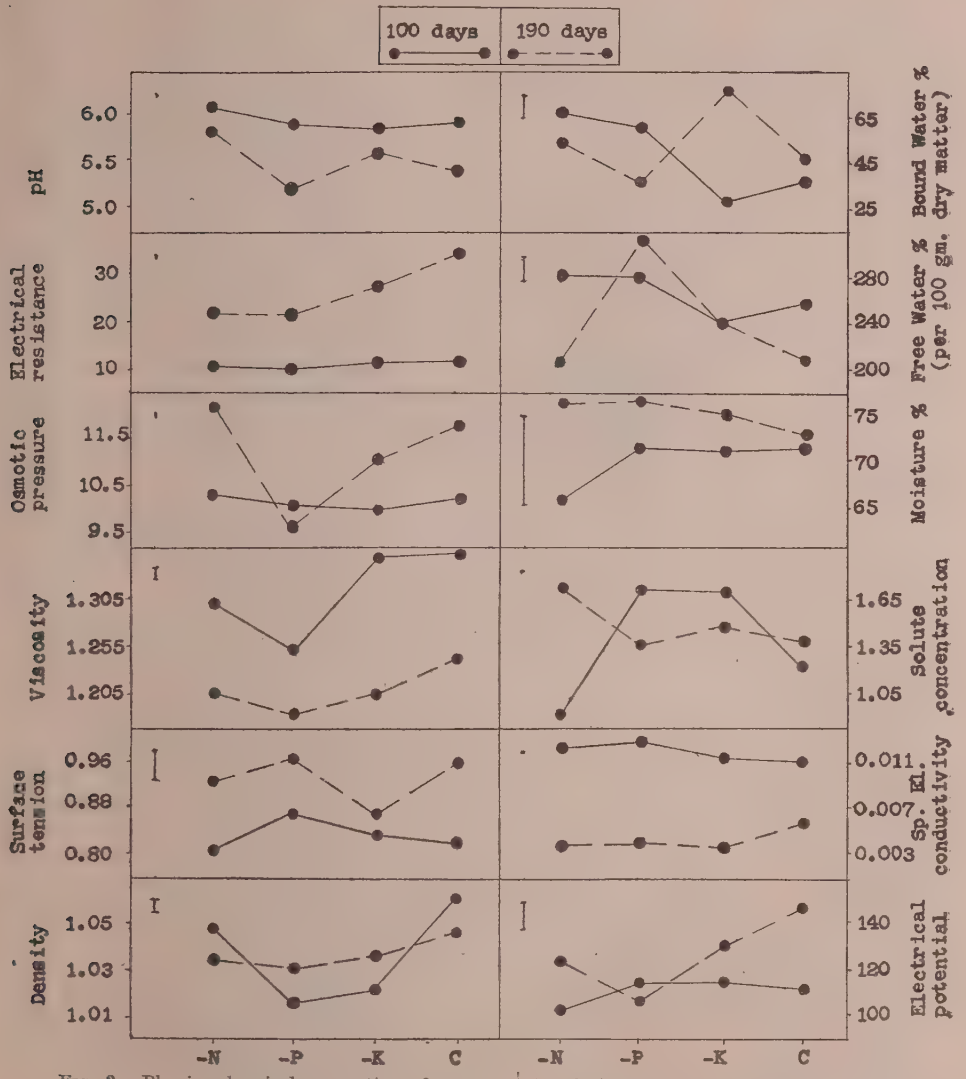

FIG. 3. Physico-chemical properties of sugarcane in relation to nutrient deficiencies and age.

1. Osmotic pressure .. .. .. Atmos.
2. Electrical resistance .. .. .. Ohms.
3. Electrical potential .. .. .. Milli volts.
4. Specific electrical conductivity Mhos.
5. Solute concentration .. .. gm. mol./kg. of dry material.

Discussion

Sap characteristics in relation to nutrition

Data recorded on various physico-chemical properties of sap showed the outstanding effects of certain mineral deficiencies, on these characters. A comparative study indicated that complete nutrient canes showed the highest sap density and viscosity. Solute concentration and moisture percentage were also high in complete nutrient canes during early stages (100 days). Electrical resistance of the sap increased under this culture during later stages (190 days). Increase in density and viscosity indicated beyond doubt that soluble solutes in plant sap were greater in complete nutrient canes than under different deficiencies. This was further made evident from the observation on solute concentration which increased to a maximum in complete nutrient canes, in spite of their high moisture content. Data on electrical resistance of the sap indicated that sap from the complete nutrient cane stem was generally higher in electrical resistance than the sap from canes, under mineral deficiencies. This indicated the possibility that increased viscosity and density were invariably associated with greater percentage of non-electrolytes in plant sap.

Comparative studies conducted by Lal *et al.* [1954] also indicated that complete nutrient canes showed an all round improvement in growth characters, dry matter accumulation and root extension per day. Plants under this treatment also showed high net assimilation rate and more efficient carbohydrate and nitrogen metabolism [De,1952] at successive stages. It, therefore, became evident that higher efficiency of carbohydrate and nitrogen metabolism was the principal cause for efficient growth and for higher concentrations of solutes, for improvement in density and for viscosity of the sap in complete nutrient cultures.

Nitrogen deficiency was found to markedly improve the osmotic pressure, bound water and bound/free water ratio at both the stages of the life cycle. The latter essentially indicated that absence of nitrogen improved the colloidal conditions on the sap as a result of which a larger percentage of bound water was held in the tissues. The nature of these colloidal materials could not be said with certainty at present. Comparative studies of carbohydrate and nitrogen metabolism showed that in absence of this ingredient there was a slight improvement in the accumulation of hexoses and sucrose which failed to be elaborated into complex nitrogenous organic compounds in sugarcane. The relatively high percentage of amino acids in nitrogen deficient canes further indicated the failure of nitrogen metabolism reactions to proceed beyond a certain extent causing poor protein and amide synthesis. The relatively higher percentage of amino acids, hexoses and sucrose in deficient canes would thus naturally improve the concentration of osmotically active solutes as a result of which this sap character improved to a certain extent.

Another equally important effect of nitrogen deficiency was relatively low moisture content and poor free water content of the tissues. Electrical potential also fell down to a low level in spite of high osmotic pressure of the sap. Such a fall in electrical potentialur must natally be attributed to poor oxidation-reduction

reactions in plant sap under nitrogen deficiency. De [1952] showed that the absolute amount of all the mineral ingredients —N, P_2O_5, K_2O, Mg, Ca, S -contained in the entire plant was lower in deficient canes as compared to the control. The sap obtained from such plants, therefore, would naturally be poorer as compared to the control, in the content of mineral ingredients. The slight increase in *p*H of the cane sap under nitrogen deficiency required careful explanation. One possibility was that in absence of nitrogen small amount of ammoniacal nitrogen accumulated in deficient canes [De, 1952]. This might be responsible for raising the *p*H of the sap.

Under phosphorus deficiency surface tension and specific electrical conductivity of sap were markedly improved. The improvement in the latter direction may be caused by a relatively larger quantity of electrolytes present per unit volume of the sap. The nature of the electrolytes should be undoubtedly such as might raise the surface tension of the plant sap as well. It was difficult to visualise the nature of such substances accumulating in sap under P deficiency conditions. It was equally significant to note that phosphorus deficiency lowered the density and viscosity of the sap. This might partly be due to (i) poor sucrose content of the sap under phosphorus deficiency [Singh, 1941], and (ii) presence of such other soluble solutes which had the characteristic effect of lowering the viscosity of the sap. At least the decline in viscosity could not be associated with a dilution effect for two reasons, (*a*) increase in the density of the sap and (*b*) relatively low moisture percentage of the tissue under phosphorus deficiency. Poor electrical resistance and solute concentration showed the existence in colloidal suspensions or true solutions of substances which are electrolytes and which increased the density and viscosity of the sap under such conditions as well.

Recorded observations showed that absence of potassium improved physico-chemical properties to a lesser extent than deficiencies of either N or P. The slight improvement in total solute concentration under potassium deficiency during later stages and a slight increase in electrical potential and in free water content during early stages were the few instances of any marked significance in potassium deficient canes. Absence of potassium towards the later stages of the life cycle, on the other hand, lowered the surface tension and specific electrical conductivity most ; during early stages its deficiency tended to decrease the osmotic pressure, *p*H and bound water content to the minimum. Absence of potassium thus decreased the colloidal content as a result of which quantity of bound water held in the tissues was lowered. The concentration of electrolytes was also reduced causing a marked decline in the specific electrical conductivity of the sap during later period of the life cycle.

Effect of age on sap characteristics

It was also indicated that the early stage of the life cycle was more favourable for high viscosity, specific electrical conductivity, *p*H and free water content. Early stage of 100 days was the stage of maximum growth rate, highest mineral uptake and high physiological efficiency of sugarcane plant in general [De, 1952]. Greater

mineral uptake naturally resulted in improvement of specific electrical conductivity, while high concentration of all soluble complex carbohydrates and nitrogen fractions accumulated in the sap. It was also significant to note that the later stage of 190 days was a stage when the moisture content, bound water and bound/free water ratio, attained relatively high values. Even the electrical resistance was relatively high. Osmotic pressure and solute concentrations were also higher. The improvement in these directions showed the possibilities of greater concentration of non-electrolytes such as sucrose accumulating in the cane tissue during this period. These sugars contributed also to the improvement in the density of the sap.

Effect of plant parts on sap characteristics

It was equally significant to note that the sugarcane leaf sap showed a relatively higher specific electrical conductivity and electrical potential than the stem sap. There was a downward gradient of potential from the leaf to the basal region of the stem as a result of which the soluble solutes tended to accumulate in the basal regions of the sugarcane stem. This accumulation in the stem resulted in higher density, solute concentration and electrical resistance of the stem sap when compared to leaf sap. Since majority of the solutes in the lower stem existed either in a soluble form or colloidal state, their increasing accumulation towards maturity helped in increasing the bound water content of the stem tissue as well. Bound water expressed as the percentage of total water or dry matter was therefore found to be higher in the stem. Similarly the bound/free water ratio was invariably higher in the stem. In the stem sap, therefore, sufficient colloidal forces developed to retain the moisture intact even against the forces of transpiration and evaporation developing in the leafy regions.

Symptoms of mineral deficiencies

In so far as the effect of nutrient deficiency for nutrition was concerned, absence of nitrogen and phosphorus appeared to be more potent in altering various sap characteristics than slackened supply of potassium under the conditions of these investigations.

Certain symptomological changes might, therefore, be related to the specific conditions of mineral deficiency. Relative to the control, nitrogen deficiency for instance, lowered vegetative vigour, reduced height, tillering, leaf area and cane weight. Its absence also lowered density, viscosity, electrical potential, moisture percentage and percentage of free water in the tissues. Slakened supply of the nitrogen, on the contrary, also increased osmotic pressure, *p*H, bound water content and the ratio of bound/free water slightly above that recorded for complete nutrient canes.

Phosphorus deficiency checked vegetative growth causing poor yield of sugarcane as compared to the control. Internally, absence of phosphorus caused low density and viscosity ; poor osmotic pressure, solute concentration, bound water and bound/free water ratio were recorded at later stages. Phosphorus deficiency also increased surface tension and specific electrical conductivity of sap. Potassium

deficiency was least effective. It tended to improve the solute concentration during later periods and electrical potential and free water content during early stages of sugarcane growth. Surface tension and specific electrical conductivity were also lowered during later periods, while osmotic pressure, electrical resistance, *p*H, bound water and bound/free water ratio were reduced during the early stages only. In explaining the nature of nitrogen, phosphorus and potassium deficiency effects in relation to general problems of growth, disease and drought resistance, such symptoms are likely to be of some use. The extent to which these will be helpful in nutritional investigations, in general, would be elucidated in subsequent papers.

Summary

The effect of nitrogen, phosphorus and potassium deficiencies on growth, juice quality and physico-chemical properties of sap was investigated in sand nutrient cultures. Relative effects of age, plant parts and mineral deficiencies on these characteristics were statistically evaluated.

Canes grown under complete nutrition showed the highest density and viscosity of the sap. Solute concentration and moisture percentage at the early stages of 100 days and electrical resistance of sap during later periods of 190 days were also relatively high in complete nutrient canes as compared to the deficient ones.

Nitrogen deficiency improved osmotic pressure, bound water and bound/free water ratio. Low total moisture and free, water, poor electrical potential and lower acidity were also recorded in nitrogen deficient sugarcane. These internal sap characteristics were associated with poor vegetative vigour of the plant, in general.

Under phosphorus deficiency, surface tension and specific electrical conductivity were improved. Density and viscosity were lowered; poor electrical resistance, low solute concentration and low osmotic pressure were also recorded. These were accompanied by reduction in vegetative growth and yields as well.

Potassium deficiency induced slight improvement in solute concentration during later stage of 190 days, and electrical potential and free water content during early stage of 100 days. At 190 days, surface tension and specific electrical conductivity were lowered. At 100 days, osmotic pressure, *p*H and bound water content were reduced. The significance of these changes has been discussed in relation to the other characteristics of sugarcane plant.

In general, the early stage was more favourable for viscosity, specific electrical conductivity, *p*H and free water content. All these characteristics coincided with the stage of maximum growth rate, highest mineral uptake and high physiological efficiency of sugarcane plant recorded during this period.

The leaf sap was invariably higher in specific electrical conductivity and electrica potential than the stem sap. There existed a downward potential gradient from a region of high potential in the leaf to a region of low potential in the basal stem. Significance of this gradient in the accumulation of solutes in the basal region has been pointed out.

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EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM ON GROWTH CHARACTERS AND PHYSICO-CHEMICAL PROPERTIES OF SUGARCANE SAP

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(With 5 Text-Figures)

NITROGEN affects the growth, composition, yield and dry matter accumulation of sugarcane. Very often its responses are regulated by the season of growth, form of nitrogen, quantity of nitrogen, location, soil type, water supply, character of soil and associated levels of phosphorus and potassium. With increasing nitrogen, water content, reducing sugars, total and alcohol soluble nitrogen and electrical conductivity of the sap are improved while sucrose and purity are reduced [Das, 1936; Sampaio, 1945]. Moisture content, reducing sugars total sugar/nitrogen and total sugar/total dry weight ratio also show wide variations [Borden, 1948], alongside improvement in vegetative growth when nitrogen is added [Rege and Sannabhadti, 1944; Vallance, 1948*a*,*b*].

Potassium is equally effective in improving growth, yield and juice quality [Wilcox, 1944; Craig, 1940] when applied in combination with phosphorus and nitrogen [Lintner, 1939]. When applied with nitrogen, phosphorus improves biological condition and internal capacity of soil to sustain crops. Improvement in yield results irrespective of the form in which it is applied [Ayres, 1939]. Its application affects intake of phosphorus and other ingredients [Rege and Sannabhadti, 1944], and results in larger number of tillers [Potter, 1947]. Potassium, on the other hand, is more readily absorbed during early stages [Borden, 1944] while quantity taken up at later stages is proportional to the quantity supplied [Hartt, 1934] and altered concentrations of other ingredients. Useful responses of nitrogen, phosphorus and potassium are noticed when these ingredients are applied in adequate amounts.

This article elucidates the responses of N, P and K when the three ingredients were applied to sand filled pots. The extent of improvement in (i) various growth attributes, (ii) juice quality, and (iii) the physico-chemical properties of the sap as a result of these treatments has been indicated. Special attention was directed to study the changes in density, surface tension, viscosity, osmotic pressure, solute concentration, electrical resistance, specific electrical conductivity, *p*H and electrical potential of sap, total, bound and free water content of tissues. These showed the complex nature of the fertilizer effect and indicated the caution needed in

interpretting the results of fertilizer trials only in terms of growth and juice characters. They also pointed out the desirable physico-chemical qualities of the sap which were usually associated with better growth and yield of sugarcane.

Experimentation

Sugarcane variety Co. 453 was grown under conditions of pot culture and supplied with different levels of ammonium sulphate (N) mono-basic-potassium hydrogen phosphate (P_2O_5) and sulphate of potash (K_2O). The procedure of raising setts was similar to that adopted in the earlier investigations [Singh, 1941, 1942]. The details of the conditions of the culture were as follows :

1. *Variety* — Co. 453.
2. *Pot size* — 12 in. × 18 in.
3. *Quantity of sand used* — 33 kg.
   30 kg.
   of well washed sand.

4. *Treatments*

(*a*) Nitrogen series

1951-52	0, 20, 40, 60 and 80 ppm. of N ;
1952-53	0, 30, 60, 90 and 120 ppm. of N ; applied as ammonium sulphate

(*b*) Phosphorus series

1951-52	0, 20, 40, 60 and 80 ppm. of P_2O_5 ;
1952-53	0, 15, 30, 45 and 60 ppm. of P_2O_5 ; applied as KH_2PO_4

(*c*) Potassium series

1951-52	0, 20, 40, 60 and 80 ppm. of K_2O ;
1952-53	0, 15, 30, 45 and 60 ppm. of K_2O ; applied as K_2SO_4.

All quantities were calculated on weight of sand used.

5. *Basal manuring*

(*a*) Nitrogen series	Hoagland's nitrogen deficiency solution 16 litres in all per culture.
(*b*) Phosphorus series	Hoagland's phosphorus deficiency solution 16 litres in all per culture.
(*c*) Potassium series	Hoagland's potassium deficiency solution 16 litres in all per culture.

6. *Time of application of nutrients*

(*a*) $(NH_4)_2SO_4$, KH_2PO_4 and K_2SO_4 were applied in full dose at planting.

(*b*) Basal nutrient solution was added in instalments of 8 litres at planting and the remaining 8 litres in four monthly instalments of 2 litres each.

7. *Time of planting setts*, 1951-52 — 4th March 1951
1952-53 — 21st February 1952

8. *Time of transplanting germinated setts*, 1951-52 — 20th March 1951
1952-53 — 4th March 1952

9. *Replicates* — four per treatment

10. *Total number of cultures* — Series (*a*) 4×5 : 20; Series (*b*) 4×5 : 20; Series (*c*) 4×5 : 20

The experiment involved the study of the effect of five levels of each of the three ingredients at two stages in the life cycle. The responses were analysed in terms of different external growth characters and physico-chemical properties of the sap. The procedure of recording these characteristics was exactly similar to that described earlier [Lal and Tandon, 1955, 1957].

The growth data were also utilized for the determination of (*a*) maximum possible yield as a result of the application of the three nutrients, (*b*) the basic level of each nutrient in the medium of growth, and (*c*) expected yield under each level of manure applied. For the determination of these important characteristics the method recommended by Wilcox [1930] was followed. The extent to which the expected values tallied with the recorded yield of sugarcane under different levels was determined and the discrepancies, if any, were pointed out. Finally the requirement of the three principal nutrients for optimum growth, juice quality and physico-chemical properties of sap was calculated by adding to the basic level, the additional quantity of nutrient needed to produce optimum effect.

Results

A. *Growth characters in relation to the application of nitrogen, phosphorus and potassium*

General. In the first year of the experiment (1951-52), the three elements and their concentration had a significant effect on various growth and juice characters. The effect of element-concentration interaction was, however, significant on shoot number, cane weight and percentages of total solids, sucrose and purity coefficient of sap only. In the second year (1952-53) concentration of nitrogen had a less significant effect than the stages of plant growth which markedly affected shoot number, height and cane weight. Stage of growth was equally significant in effect when varying levels of phosphorus were applied. Potassium, if at all, indicated a highly significant effect on number of shoots and leaf weight only.

Shoot number. Shoot number increased with each addition in the dose of nitrogen reaching the highest value under 80 ppm. N. With phosphorus, no significant variations in shoot number were noted beyond 20 ppm. of P_2O_5. In the potassium series, again, majority of the concentrations showed insignificant effects (Fig. 1).

In the second year of experiment optimum effects were again recorded at 120 ppm. of N, but the effects of increasing doses beyond 30 ppm. were largely insignificant. Phosphorus, on the other hand, showed highest tillering at 45 ppm.; differences between all ranges beyond 15 ppm. of P_2O_5 were again insignificant (Fig. 2). So far as potassium was concerned, no marked effects of various doses were noted. It appeared, therefore, that for inducing high tillering a high dose of nitrogen (80-120 ppm.) combined with a medium dose of phosphorus (20-45 ppm. P_2O_5) would be a desirable combination.

Leaf number. Number of leaves on the plant attained was highest under 80 ppm. of nitrogen, 60 ppm. of P_2O_5 and 40 ppm. of K_2O in 1951-52. The improvement recorded under 80 ppm. N was highly significant. The effects of additional doses of phosphorus and potassium, were not significant at all (Fig. 1). In the second year 90 ppm. of nitrogen again showed the best response. As against this the effects of increasing levels of phosphorus and potassium were largely insignificant, although a slight tendency of useful effect was noted at 45 ppm. of P_2O_5 and 30, ppm. of K_2O (Fig. 2).

Height. Effect of increasing levels of the three fertilizers on cane height was highly significant under 80 ppm. of nitrogen, 80 ppm. of P_2O_5 and 20 ppm. of K_2O in the first year of the experiment (Fig. 1). Shoot height also attained high level under similar doses of nitrogen and phosphorus; potassium at 60 ppm. K_2O showed a more helpful effect. In the second year again, nitrogen showed the best response under 90 ppm. Increasing levels of phosphorus and potassium failed to show any significant response on shoot height (Fig. 2).

Leaf weight. Weight of foliage showed optimum effects at 80 ppm. of nitrogen but phosphorus and potassium again failed to indicate any significant effect (Fig. 1). In the second year 90 ppm. of nitrogen and 45 ppm. to P_2O_5 showed a significantly positive response. Potassium, on the contrary, tended to show some useful effect at 45 ppm., but the increase over the control, was insignificant. On this character again nitrogen appeared to be more predominating in effect than either phosphorus or potassium (Fig. 2).

Weight of stem. In the first year of experiment, weight of millable canes was found to be markedly increased under 80 ppm. of nitrogen and 20 ppm. of phosphorus and potassium. Higher doses of P and K showed no significant response (Fig. 1). In the second year, total weight of the stem and sheath again attained the highest value under 90 ppm. of nitrogen. and 45 ppm. of P_2O_5 and K_2O. Differences amongst individual treatments were however, not as apparent as in the first year of the experiment. Here again, a more helpful effect of nitrogen than either phosphorus or potassium was recorded (Fig. 2).

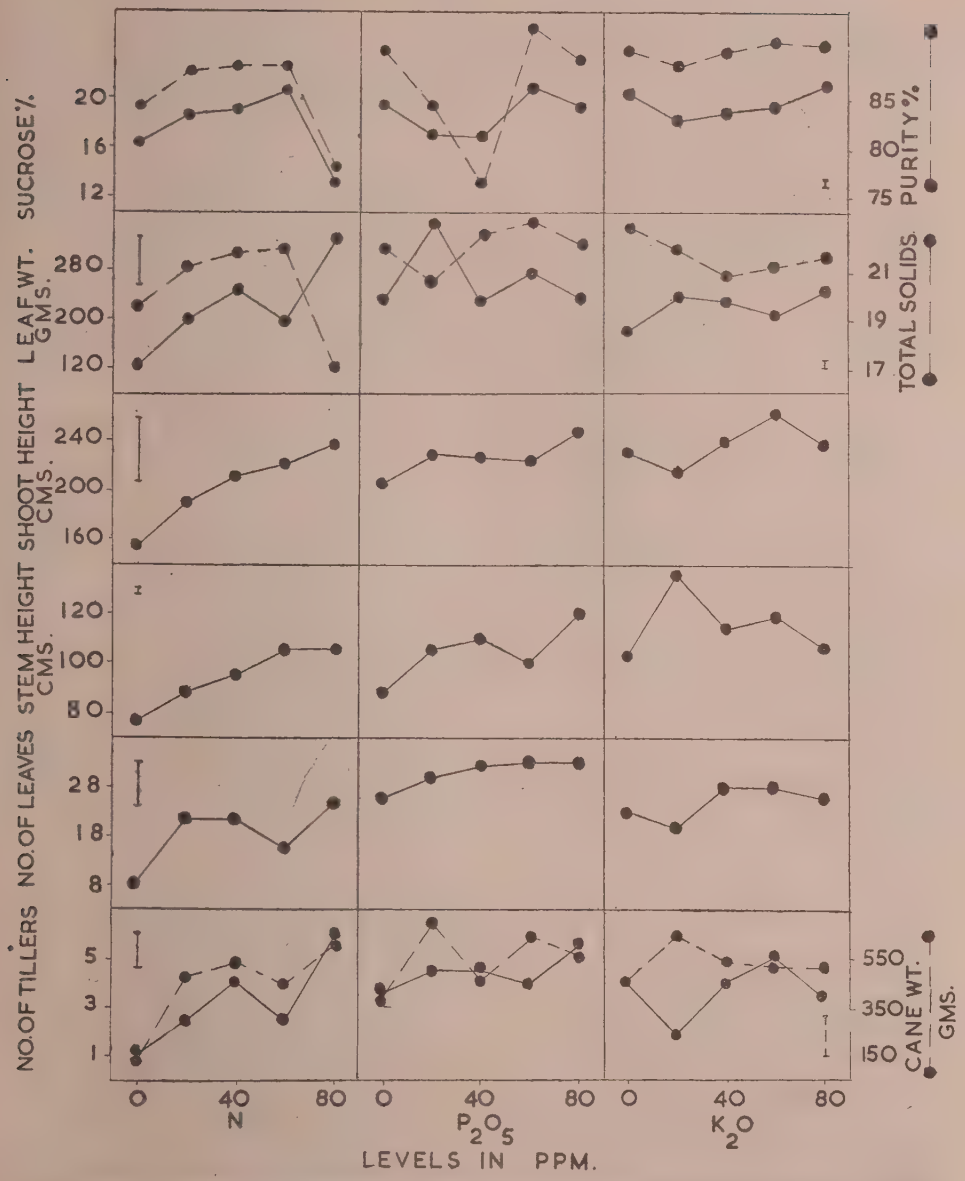

FIG. 1. Growth characters of sugarcane in relation to varying levels of N, P_2O_5 and K_2O (1951-52).

Root weight. Root weight of the plant reached high value under 90 ppm. of nitrogen. Phosphorus showed a highly significant effect on root weight at 45 ppm. of P_2O_5. A slight helpful effect of potassium was also noted at 15 ppm. but the differences amongst this and other lower doses of potassium were largely insignificant. Phosphorus and potassium beyond 45 ppm. showed a significantly deleterious effect on the root growth (Fig. 2).

Juice characters. On juice characters, application of fertilizers showed a marked effect. Thus, total solids attained significantly high value at 60 ppm. of N and P_2O_5 while K appeared to be not helpful at all. So far as sucrose was concerned, the effect of potassium at 80 ppm. K_2O, of phosphorus at 60 ppm. P_2O_5 and of nitrogen at 40 ppm. N were significant. In the case of purity coefficient, 60 ppm. of all the ingredients was most effective. It therefore, appeared that application of potassium, though not helpful on other growth characters appeared to be highly useful on sucrose and purity of juice (Fig. 1).

B. *Effect of nitrogen, phosphorus and potassium on various physico-chemical properties of leaf sap*

Physico-chemical properties of the leaf sap were investigated at 104 days in the life cycle. Statistical examination of the data showed that the effect of levels of nitrogen was highly significant on surface tension, osmotic pressure, solute concentration, electrical resistance, specific electrical conductivity, *p*H and electrical potential of the sap. Density and viscosity were less affected by nitrogen levels. Phosphorus application also showed more or less similar responses. Potassium, on the contrary, affected all the physico-chemical characters under study.

Density. Density of the sap was relatively high under 60 ppm. of nitrogen but declined at higher levels. The effects of added nitrogen within the range of 0—90 ppm. were, however, insignificant. Similarly phosphorus showed no significant differences beyond the control when applied at various levels. Application of potassium at 45 ppm., however, significantly improved the density of the sap (Fig. 3).

Surface tension. Application of nitrogen at 60 ppm. tended to improve the surface tension of the sap but further increases were deleterious. Decline in surface tension beyond 60 ppm. was more significant than observed improvements with added nitrogen under relatively low levels of N. Application of phosphorus at all levels beyond 15 ppm. of P_2O_5 increased this character markedly above the control. Similarly application of potassium beyond 15 ppm. K_2O was equally effective in increasing the surface tension to the highest value at 45 ppm. of K_2O (Fig. 3).

Viscosity. Nitrogen also significantly increased the viscosity at 30 ppm. level but decreased it at higher levels of 90 ppm. Phosphorus showed no useful effect on this character throughout the entire range. Potassium on the contrary, showed significant reductions in viscosity at 15 ppm. Slight improvement in viscosity at 45 ppm. of K_2O above that of 15 ppm. K_2O was noted. In none of these cases viscosity attained values higher than that recorded for the control (Fig. 3).

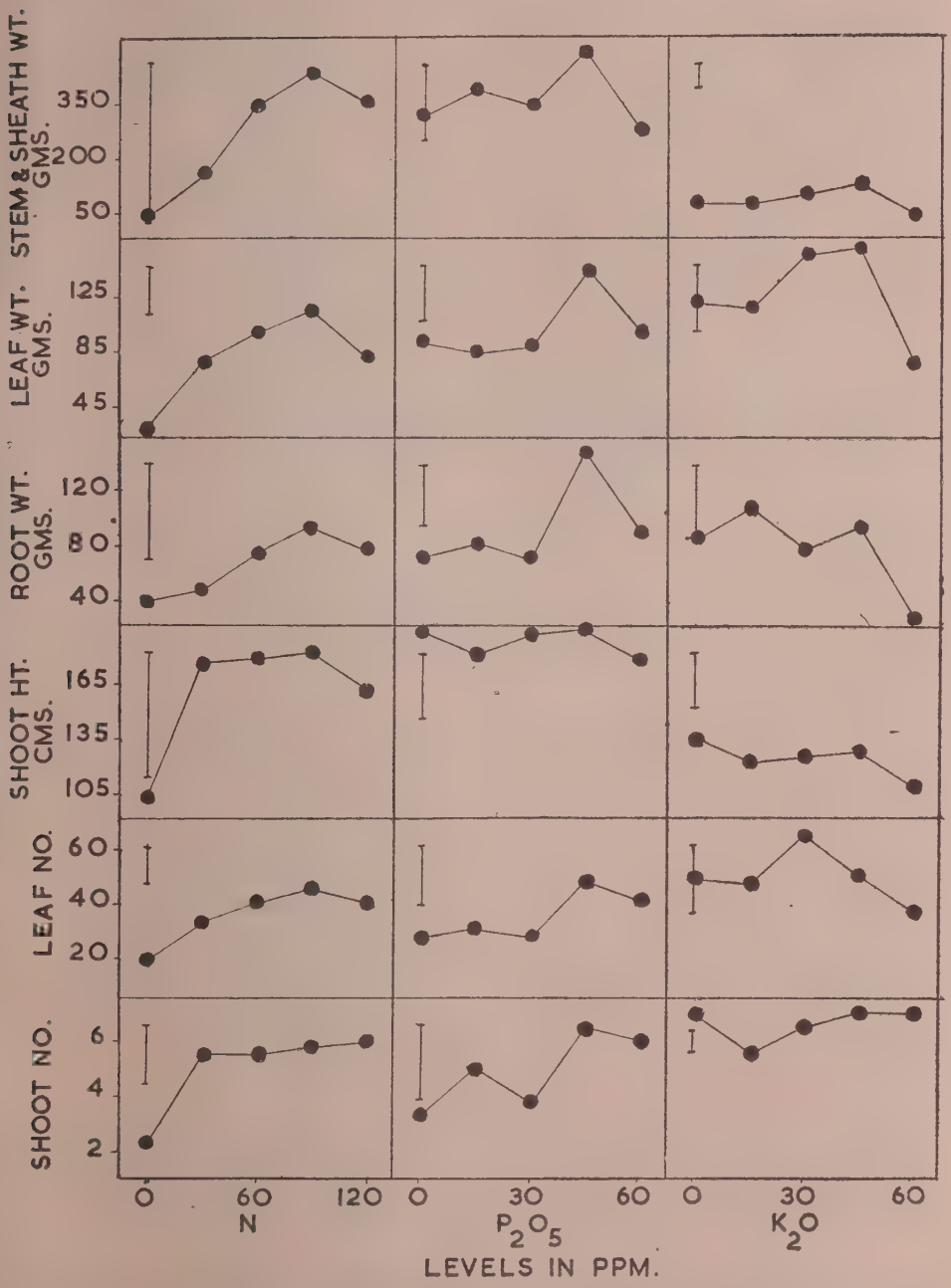

FIG. 2. Growth characteristics of sugarcane in relation to varying levels of N, P_2O_5 and K_2O (1952-53)

Osmotic pressure. Osmotic pressure attained significantly high values under 60 ppm. of nitrogen while higher doses decreased the osmotic pressure of the sap. Phosphorus markedly improved this character at 45 ppm. of this ingredient. Potassium showed the best effect at even higher levels of 60 ppm. K_2O_5. Relatively, higher doses of potassium were more helpful than the corresponding levels of phosphorus and nitrogen in inducing high osmotic pressure of the sap (Fig. 3).

Solute concentration. Concentration of solutes in the leaf sap also increased with added nitrogen, reaching the highest concentration at 90 ppm. N. Further addition of nitrogen proved injurious. Similarly a 60 ppm. dose of P_2O_5 appeared to be more helpful than lower doses in improving solute concentration (Fig 3). Addition of potassium, however, caused a definite decline inconcentration of solutes when compared to the control.

Electrical resistance. Electrical resistance of the sap increased under lower levels of 30 ppm. N but showed a consistent fall with increasing dose of this ingredient. With phosphorus, a concentration of 30 ppm. P_2O_5 was more helpful than other levels. Potassium showed a marked improvement in electrical resistance of the sap at 15 ppm. of K_2O. but indicated less helpful effects at higher doses (Fig. 3).

Specific electrical conductivity. Specific conductivity of the leaf sap showed a significant fall at 30 ppm. but gradually showed significant improvement with added nitrogen reaching the highest at 120 ppm. of this ingredient. Addition of phosphorus showed a reduction in specific electrical conductivity, reaching the lowest value under 60 ppm. of P_2O_5. Similarly, application of potassium caused a marked decline in specific electrical conductivity below that of the control at all ranges of potassium application (Fig. 3).

pH. The sap became more acidic under lower levels of nitrogen, but tended to attain normal values at the highest level of 120 ppm. N. Lowest *p*H was recorded at 30 ppm. of nitrogen. Application of phosphorus also lowered the *p*H value but the sap was relatively more acidic at lower levels of 15 ppm. of P_2O_5, than at higher ranges of 60 ppm. Under none of these doses of phosphorus, *p*H values similar to that under control were recorded. In potassium, the sap under 15 ppm. of K_2O tended to show slightly higher *p*H than the control, but evinced a marked reduction in *p*H at 30 ppm., and other higher ranges of 45 and 60 ppm. K_2O (Fig. 3).

Electrical potential. Electrical potential of the sap was highest at 30 ppm. of nitrogen, and significantly decreased as the nitrogen dose was increased. A similar effect was again noted at 15 ppm. of P_2O_5, when the electrical potential was highest. With potassium, a 30 ppm. dose of K_2O improved the electrical potential of the sap, while high doses again lowered this potential (Fig. 3).

C. *Effect of fertilizers on the physico-chemical properties of sugarcane stem sap*

Effect of nitrogen and phosphorus on various physico-chemical properties of stem sap was investigated at 204 days in the life cycle. Statistical analysis

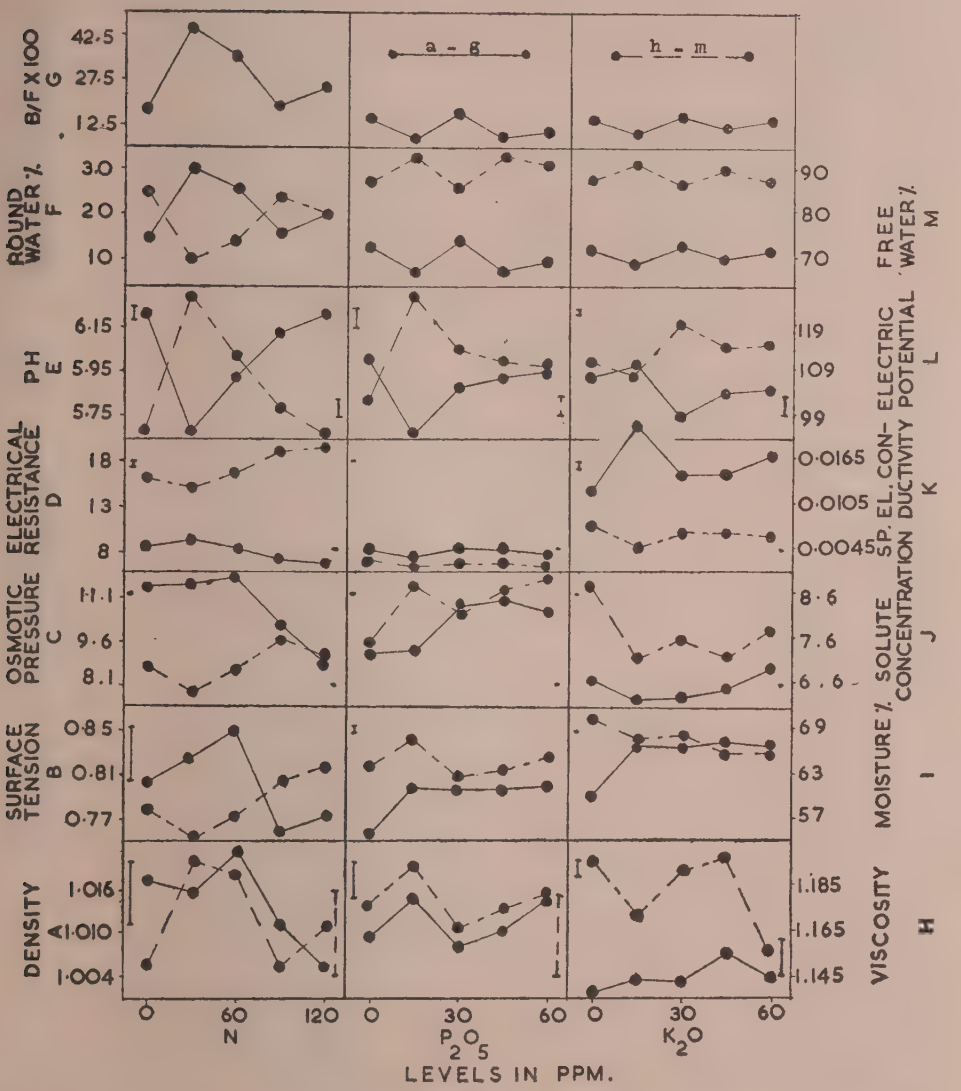

FIG. 3. Physico-chemical properties of sugarcane leaf sap in relation to verying levels of N, P_2O_6 and K_2O.

1. Solute concentration .. gm. mol./kg. of dry material.
2. Osmotic pressure .. Atmos.
3. Electrical resistance .. Ohms.
4. Electrical potential Milli-volts.
5. Sp. Elect. Conductivity Mhos.

revealed that while nitrogen levels had a significant effect on all the characters different doses of phosphorus showed significant response on the density, viscosity, osmotic pressure, solute concentration, electrical resistance and specific electrical conductivity of the sap only.

Density. Density of the sap increased to a high value under 90 ppm. of N and showed a significant improvement over the control. Higher doses of 120 ppm. lowered density of stem sap markedly. With phosphorus, a significant depression in the density at 15 ppm. of P_2O_5 was recorded in comparison to the density under 30 and 60 ppm. P_2O_5 cultures (Fig. 4).

Surface tension. Surface tension also increased significantly over the control at 60 ppm. of nitrogen but no marked differences were recorded in this character under various doses of phosphorus. In the former case all other treatments excepting 60 ppm. N showed insignificant variations from the control whereas a dose of 90 ppm. nitrogen even reduced the surface tension below that recorded for 60 ppm. cultures (Fig. 4).

Viscosity. Viscosity of sap was lowered significantly under all levels of nitrogen below that of the control. All levels between 30-90 ppm. N showed no significant variation while a dose of 120 ppm. N appeared slightly better than lower levels of 30-90 ppm. N. At this highest level also viscosity never attained the level recorded for the control (Fig. 4). In repsonse to added phosphorus, viscosity of the stem sap was reduced below that of the control in cultures supplied with 15-45 ppm. of P_2O_5. The highest level of 60 ppm. showed significant increase in viscosity over that of the control.

Osmotic pressure. A marked improvement in osmotic pressure of the stem sap was noted with added nitrogen reaching a significantly high level at 90 ppm. Each addition in dose, showed a significant effect in improving this property up to a critical concentration of 90 ppm. N, beyond which further increase in nitrogen appeared deleterious (Fig. 4). As against this, phosphorus showed the most helpful effects at 60 ppm. P_2O_5. Lower levels of 15 ppm., appeared silghtly deleterious, in as much as the osmotic pressure fell down below that recorded for either the control or other ranges of phosphorus concentration (Fig. 4).

Solute concentration. Solute concentration attained highest value at 120 ppm. of nitrogen and 45 ppm. of P_2O_5. At both these ranges significant improvements were recorded over other levels of fertilizers (Fig. 4).

Electrical resistance. Electrical resistance of stem sap was highest at 90 ppm. of nitrogen and was not altered significantly by higher concentrations beyond 90 ppm. of nitrogen. Similarly 60 ppm. of P_2O_5 induced highest electrical resistance of the sap as compared to all other treatments. Here again highly significant effect of each level over the control was recorded (Fig. 4).

Specific electrical conductivity. Specific electrical conductivity of the stem sap fell down with each addition of nitrogen to a very low value at 90-120 ppm. N. The reductions below that of the control were highly significant. In response

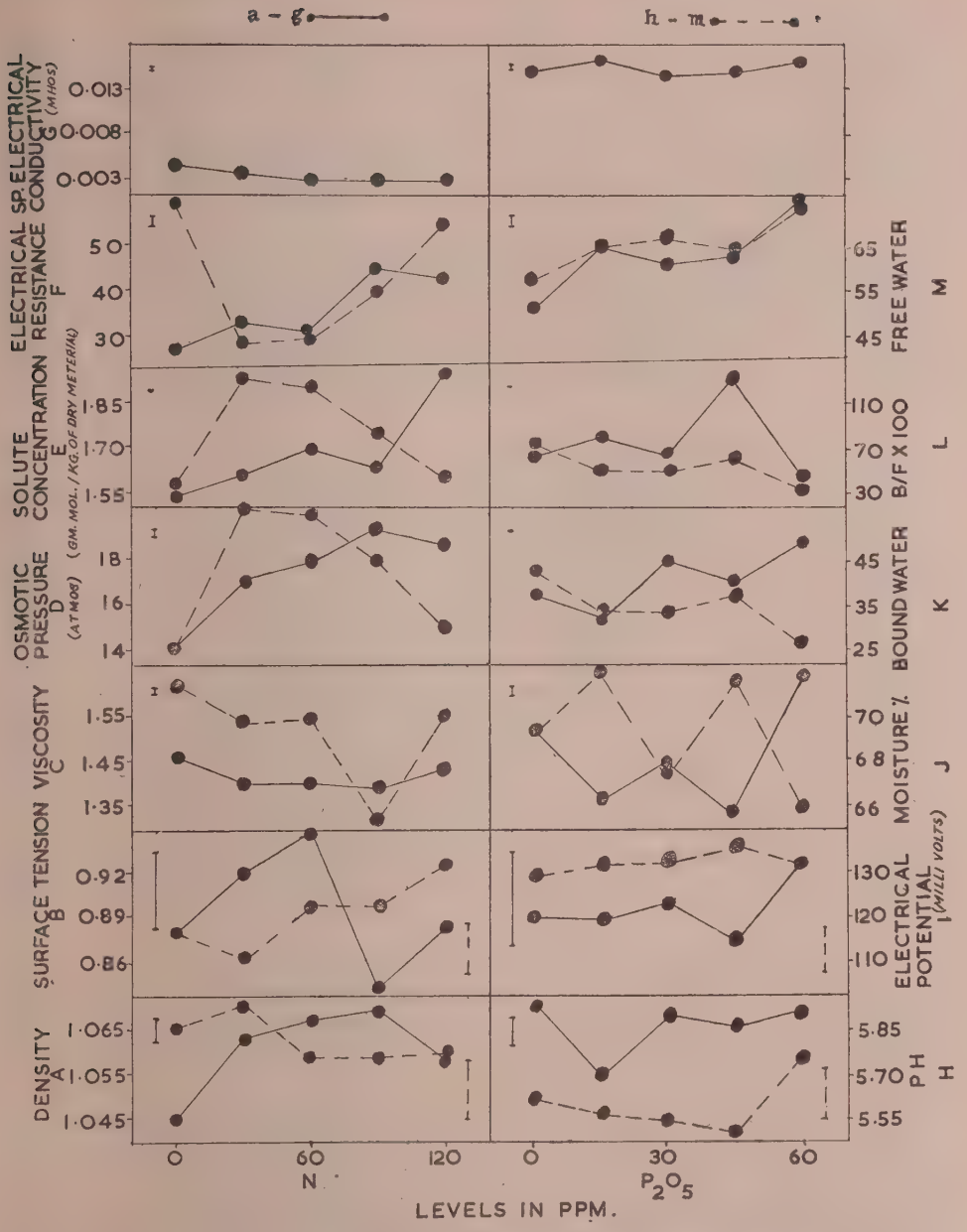

FIG. 4. Physico-chemical properties of sugarcane stem sap in relation to varying levels of N and P_2O_5.

to phosphorus again, slight improvement in specific electrical conductivity was recorded at 15 ppm. P_2O_5, while higher levels appeared to lower this physico-chemical property (Fig. 4).

pH. *p*H of the stem sap remained unaffected by the addition of either nitrogen or phosphorus. In all cases a narrow range of *p*H between 5·75-5·95 in nitrogen series, and between 5·50-5·575 in the phosphorus series, was recorded (Fig. 4).

Electrical potential. Electrical potential improved markedly with the dose of nitrogen reaching 131·5 milli-volts under 120 ppm. of N. The improvements were significant when compared to the control or 30 ppm. cultures. In the phosphorus series, highest electrical potential of 136 milli-volts was recorded at 45 ppm., but the differences amongst various treatments were not significant. Nitrogen appeared to have a more significant effect than phosphorus on this sap characteristics (Fig. 4).

Water fractions in tissues

Bound water content of leaf at 104 days in the life cycle attained relatively high values at 30 ppm. N ; free water on the contrary, was higher in control. Bound/free water ratio also attained high values under 30 ppm. N. This was true with both the methods of expressing the ratio in terms of the quantity present in 100 gm. of total water or in 100 gm. of dry matter. As against these water fractions, the percentage of total moisture in the tissues increased with added nitrogen, reaching the highest values under 120 lb. N (Fig. 3). Total moisture under phosphorus feeding improved to high values at 15 ppm. P_2O_5. Bound water was high under 30 ppm. P_2O_5. Free water and bound/free water ratio also attained higher levels at 15 ppm. of P_2O_5. Expression of bound water or free water in terms of total moisture or dry weight, did not materially alter the nature of fertilizer response. Application of potassium at 30 ppm. raised the bound water content ; at 15 ppm. K_2O, this element showed a tendency of increasing free water content when expressed as percentage of total water. On dry weight basis, free water was relatively high in control while bound water attained higher values at 30 ppm. level of this element (Fig. 3).

In the stem sample at 205 days, increase in level of nitrogen to 30 ppm. raised bound water content when expressed as percentage of total moisture. Free water expressed on the same basis was, on the contrary, higher in the control. The ratio bound/free water was high at 30 ppm. N. On dry matter basis, the response of nitrogen was more or less similar.

With increasing phosphorus, bound water fell down below that of the control while free water increased slightly reaching high values at 60 ppm. of P_2O_5. The ratio bound/free water was, however, high in control. On dry matter basis, 45 ppm. of P_2O_5 raised the bound water content of the stem. Free water and bound/free water ratio were relatively high at lower levels of 0-15 ppm. of P_2O_5 (Fig. 4).

Discussion

A. Expected and observed yields

When utility of the three ingredients in improving the standard of yield was tested by Mitscherlich's technique [Wilcox, 1930], it was found that lower levels showed at an average a higher value of *A* than the heavier doses of each ingredient. Taking the average value of A it was found that nitrogen showed the maximum possibility of improving the yield of the shoot at 295 days harvest. Potassium was less helpful while phosphorus was least efficacious. In case of 104 days harvest in the second year, potassium appeared to be more helpful in improving the weight of shoot than nitrogen which in its turn, was more helpful than phosphorus. It appeared, therefore, that contrary to the general belief that potassium was not at all helpful in improving the standards of yield, the data narrated above specifically indicated some helpful effect of this ingredient.

Taking the average value of a and b as noted in Table I, the expected yields under different levels of fertilizers were calculated. It was significant to note that the yields obtained under higher doses of nitrogen, phosphorus and potassium fell short of the expected yields. In the first year of the experiment the observed yield fell short of the expected yield (68·6 per cent) at 80 ppm. level of nitrogen. Similarly under 60 ppm. of P_2O_5 the observed yields were lower (93·5 per cent) than the expected ; under 80 ppm. of potassium 94·5 per cent of the expected yield was obtained. In the second year of the investigation yields at three months harvest under 120 ppm. of N, 60 ppm. of P_2O_5 and 45 ppm. of K_2O were 71·0, 71·8 and 30·6 per cent of the expected only. It appeared that growth was limited by some conditions other than these nutrients as a result of which full exposition of growth activity could not be attained.

Table I

Maximum possible yield and basic level under different nutrients

	Nitrogen		Phosphorus		Potassium	
	1951-52	1952-53	1951-52	1952-53	1951-52	1952-53
Age of harvest (in days)	295	104	295	104	295	104
Maximum yield (gm.) a	2543	755	1009	551	1591	1112
Constant C	·122	..	0·60	..	0·033	..
Basic level (gm.) b	0·39	0·30	0·70	0·95	6·80	2·62
Basic level (ppm.)	13·0	10·0	23·3	32·0	230·0	87·0

B. *Optimum requirement*

The optimum requirement for the growth of component organs was found out by adding to the respective basic levels, the quantity of added nitrogen, phosphorus and potassium which gave the best response. Thus in the first year of the experiment at 295 days' harvest the optimum requirement varied from 93 ppm. N for various growth characters to 73 ppm. N. for juice characters. At an average 86·3 ppm. appeared to be the optimum requirement for the growth and juice characters. At 104 days harvest, however, the optimum requirement of nitrogen was higher being of the order of 105 ppm. N. It appeared, therefore, that the requirement of nitrogen for best growth during early stages was slightly higher than its requirement for good growth and better juice quality towards later stages of life cycle. As against this, it was significant to note that the requirement of phosphorus and potassium for early at 104 days' harvest was 77·0 ppm. P_2O_5 and 119·5 ppm. K_2O. These values were lower than the requirement values for these elements for a 295-day crop. Phosphorus and potassium appeared to be more essential for later growth when accumulation of sucrose was proceeding at a rapid rate.

It was equally significant to note that the optimum requirement of nitrogen for various physico-chemical properties was found to be different. It was of the order of 13·0 ppm. N for viscosity, specific electrical conductivity, total moisture and free water content ; 43·0 ppm. N appeared optimum for *p*H, bound water and bound/free water ratio. A concentration of 103 ppm. N appeared to help density, osmotic pressure and electrical resistance most. A higher concentration of 133 ppm. N appeared to help density, osmotic pressure and electrical resistance most. A higher concentration of 133 ppm. N increased solute concentration and electrical potential in a 295 days harvest. In earlier harvest, the requirement also varied from a low value of 13 ppm. N to a maximum of 133 ppm. N for different characters. Taking the average figures for the various characters it appeared that the optimum requirement of nitrogen varied within the range of 71·46-73·00 at different stages of growth.

So far as phosphorus was concerned, the optimum requirement was lowest 23·3 ppm. P_2O_5 for *p*H and specific electrical conductivity, and 38·3 ppm. P_2O_5 for density, surface tension, viscosity, electrical potential, moisture content and free water. The optimum need for osmotic pressure and solute concentration was 68·3 ppm. P_2O_5 and 83·3 ppm. P_2O_5 respectively in a 104 days' harvest. At later stages of 295 days the requirement also varied from a low value of 23·3 ppm. for density, *p*H, bound water and bound/free water ratio to a high requirement of 83·3 ppm. P_2O_5 for surface tension, viscosity, osmotic pressure, electrical resistance and free water content. Taking all these characters into consideration, a concentration of 54·45 ppm. of phosphorus appeared more helpful during early stages while 55·61 ppm. P_2O_5 appeared slightly better for later harvest. At an average the phosphorus requirement for these physico-chemical properties was lower as compared to the requirement of nitrogen.

So far as potassium was concerned its requirement did not vary appreciably for different physico-chemical properties of the sap, the entire range being of the order of 230-290 ppm. K_2O with an average of 255·58 ppm. K_2O. It would appear from Table I that sufficient quantity of effective potassium was already present in the medium of growth and that only an additional dose of 15-16 ppm. was needed to show improvement in various physico-chemical properties. In all these cases, optimum requirement was calculated on the basis of the highest value for the various physico-chemical characters recorded in these investigations. Some difficulty, however, may be felt in expressing these optimum figures for antagonistic characters such as electrical resistance and specific electrical conductivity and bound and free water which were found to be differently affected. Thus, a dose of nitrogen which caused maximum electrical resistance would undoubtedly result in relatively low specific electrical conductivity. A level which caused maximum free water content was bound to result in low bound water content of the tissue. Barring such exceptions, the optimum requirement figures succinctly pointed out the limit of various ingredient up to which their application in general would result in better physico-chemical properties of the sap and tissue.

C. *Relative development of plant parts in relation to various fertilizers*

Relative growth of different parts of the sugarcane plant under various treatments was calculated by determining total height/shoot, root weight/shoot weight, root weight/leaf weight, root weight/stem weight, and root weight/total plant weight ratios. It was significant to note that increasing levels of nitrogen resulted in the better development of the aerial parts of the sugarcane plant than the subterranean roots. In the shoot alone, larger number of tillers were formed as compared to upward elongation in height of the crop. The decline in all these ratios under the highest level of nitrogen consistently showed its influence on the better development of tillers and leaves, as compared to the growth of roots or growth in height (Fig. 5).

So far as phosphorus was concerned, the reverse was the case. All ratio between root and component parts tended to show improvement at 60 ppm. P_2O_5 level. It appeared, therefore, that roots developed better than the aerial parts and constituted a relatively larger percentage (about 19 per cent) of the total weight of the plant body. So far as the total height/shoot number ratio was concerned addition of phosphorus at 45 and 60 ppm. P_2O_5 level improved shoot number more than shoot elongation and in fact resembled the response of nitrogen.

Potassium also showed a fall in the ratio of root to other component organs of the plant as the dose was increased to 60 ppm. The fall in these ratios indicated that relatively, potassium helped the development of aerial parts more than the growth of subterranean roots. It thus showed responses similar to that of nitrogen, but quite contrasting responses when compared to that of phosphorus. The fall in height/shoot number under higher doses was more or less similar to that noted in the nitrogen and phosphorus series (Fig. 5).

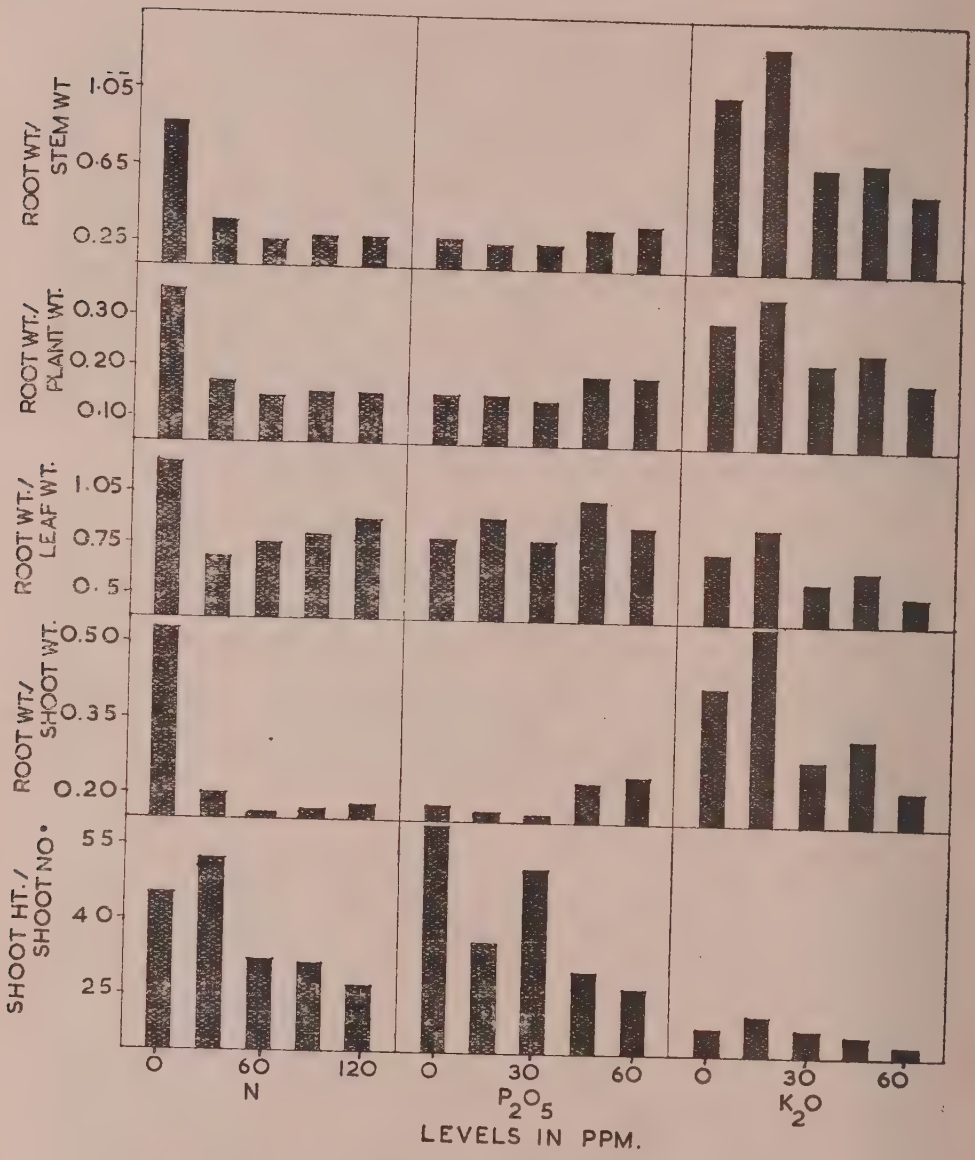

FIG. 5. Effect of varying levels of N, P_2O_5 and K_2O on various plant ratios.

D. Comparative effects of N, P and K

The utility of each successive application in increasing the total weight of the plant (E) was calculated by determining the increase in weight recorded per unit quantity of added nitrogen, phosphorus and potassium by the formula :

$$E = \frac{W_2 - W_1}{L_2 - L_1}$$

Where W_2 and W_1 were the weights recorded under the respecitve levels of L_2 and L_1.

It was significant to note that the third increase of 30 ppm. of nitrogen was most helpful in augmenting growth to the extent of 39·37 per cent per unit weight of nitrogen applied. Similarly, the third increase of 15 ppm. P_2O_5 was helpful in increasing the total weight to a maximum of 19·27 per cent per unit weight of phosphorus applied. Potassium, on the contrary, did not show any marked variation with each increase of 15 ppm. K_2O up to a total concentration of 30 ppm. K_2O. Higher doses of all the ingredients were invariably deleterious.

It was also evident that of the three ingredients, nitrogen at 80 ppm. showed the maximum number of shoots and highest sucrose percentage amongst all the 15 treatments under investigation in the first year of the experiment. Phosphorus at 60 ppm. P_2O_5 appeared best in so far as total solids, purity percentage and leafy growth was concerned. Even at 20 ppm. of P_2O_5 this ingredient appeared more helpful than all doses of nitrogen and potassium in improving the leaf weight and weight of millable canes. As against these treatments it was significant to note that added potassium at 20 ppm. showed the best response on the height of the cane while maximum shoot height inclusive of green tops was also attained when this ingredient was applied at 60 ppm. K_2O level (Fig. 1).

Comparative studies of the effects of nutrients on physico-chemical properties showed the best effects of added nitrogen at 30 ppm. on electrical potential, bound water and bound/free water ratio ; at 60 ppm. on density, surface tension and osmotic pressure ; and at 120 ppm. on specific electrical conductivity and *p*H. Maximum free water was recorded at 45 ppm. P_2O_5 and highest solute concentration was noted at 60 ppm. of this ingredient. As against these, 15 ppm. of added K_2O increased electrical resistance most while 45 ppm. improved viscosity to the maximum during the early stages of cane growth (Fig. 3).

During later periods of 205 days where nitrogen and phosphorus responses were compared, best useful effects of added nutrients were noted as follows :

Nitrogen

30 ppm.—*p*H, bound water and bound/free water

60 ppm.—surface tension

120 ppm.—osmotic pressure and solute concentration

Phosphorus

15 ppm. P_2O_5—moisture percentage and specific electrical conductivity

45 ppm. P_2O_5—electrical potential

60 ppm. P_2O_5—electrical resistance and viscosity.

Summary

The effects of various levels of nitrogen, phosphorus and potassium on growth, juice quality and physico-chemical properties of the sugarcane sap have been presented in this paper. Recorded observations were statistically examined to test the significance of the fertilizer effect.

Optimum requirement of nitrogen for growth and juice characters was found to be 105·0 ppm. N during the early stages and 86·3 ppm. N during later periods. Phosphorus was needed in concentrations of 77·0 ppm. of P_2O_5 during early periods and 81·0 ppm. P_2O_5 during later stages. Potassium, on the contrary, appeared to be required in concentrations of 119·5 ppm. K_2O during early periods and 278·9 ppm. during later stages. Relatively, nitrogen was needed more for early vegetative growth while phosphorus and potassium were required in larger amounts at later stages of sucrose accumulation.

For various physico-chemical properties, the requirement varied with the property under consideration and the age of sampling. At an average, nitrogen was needed in concentrations of 71·46—73·00 ppm. N for favourable variation in these properties. Phosphorus, at a concentration of 54·45—55·61 ppm. of P_2O_5 appeared more helpful. Potassium was needed in fairly high quantities of 255·38 ppm. K_2O. The effects of these and other levels on density, surface tension, viscosity, osmotic pressure, solute concentration, specific electrical conductivity and electrical potential and *p*H of sap and bound and free water content of tissues have been presented.

Nitrogen at an average improved the growth of shoots more than that of the roots. Larger number of tillers were formed under treatments. Phosphorus, on the contrary, improved root growth more than aerial growth of shoots. In the matter of shoot development alone phosphorus resembled nitrogen in effect. Potassium gave similar responses to that of nitrogen in that, this element helped development of aerial parts more than the subterranean roots, and differed in this respect from phosphorus.

The third increase of 30 ppm. (60-90 ppm.) nitrogen was most helpful in augmenting growth per unit weight of applied nitrogen. Similarly the third increase of 15 ppm (30-45 ppm.) of P_2O_5 was slightly better than other ranges of phosphorus applied. Potassium, on the contrary, showed no useful effect on dry matter accumulation.

The significance of the relative effects of varying concentrations on growth, juice characters and physico-chemical properties has been discussed in relation to the general problems of sugarcane physiology.

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STUDIES ON TILLAGE

III.—EFFECT OF FREQUENCY OF CULTIVATION FOR SEEDBED PREPARATION, WITH AND WITHOUT FERTILIZER AND WEEDING ON THE YIELD OF WHEAT

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In previous articles of this series, the effect of variation in depth of cultivation with alternative forms of tillage implements was studied. The present article deals with yet another aspect of the problem, the extent to which land should be ploughed. Due to absence of adequate empirical data the problem still baffles the workers and remains neither disproved nor confirmed. The Indian farmer, following traditional knowledge and experience of several generations, has raised the art of cultivation to a high stage of perfection. It is not surprising, therefore, that he believes in the decline of crop yields just the extent to which the soil tilth falls short of perfection. Stewart [1947] observed there were many lessons to be learned from the study of tillage operations followed by farmers.

Snyder and Osborn [1915] though they believe in the response of crops to thorough methods of cultivation, do not think the response is sufficient enough to justify the additional expenditure incurred on it.

Russell and Keen [1938] are not sure whether crop yields are at all affected by the number and type of cultivations given to the soil. Others think the old concept of intensive preparation of seedbed for higher yields is not based on facts. Still, instances are not rare, where ploughing of land for wheat 14 to 15 times or even more is a rule rather than exception in this country. While this may be so the knowledge, of how often one should plough his land in order to keep business going during the period of high wages and falling prices, is essential.

Viewing the problem in the above light an experiment, on the effect of frequency of cultivation for seedbed preparation, with and without fertilizer and weeding, on the yield of wheat, was started at the Indian Agricultural Research Institute, New Delhi in 1950-51, and was continued each year till 1953-54.

Material and Methods

The experiment was laid out in a split-plot design, on an irrigated piece of land with 4 replications and the main-plot treatments arranged in a 4 × 4 Latin square. The details are given below :

(*a*) *Main-plot* [frequency of cultivation]

A. Ploughing 3 times throughout the preparation of land

B. Ploughing 6 times throughout the preparation of land

C. Ploughing 9 times throughout the preparation of land

D. Ploughing 12 times throughout the preparation of land

Initial ploughing in each case was given with soil inversion plough and the rest with the local wooden plough.

(b) *Sub-plot*

1st split

N_0—No manure.

N_1—Ammonium sulphate at 40 lb. nitrogen per acre.

2nd split

W_0—No weeding

W_1—One weeding

W_2—Two weeding.

Rotation : The wheat crop was preceded by cowpea for early fodder each year, on the same piece of land during the last 3 years. An idea of its physical composition and chemical constituents may be had from the following tables.

Table I

Mechanical analysis of the soil

Composition	Percentage
Coarse sand	2·96
Fine sand	64·95
Silt	11·50
Clay	17·25

TABLE II

Chemical analysis of the soil

Constituents	Percentage
Ca 0	0·67
Mg 0	0·34
K°0	0·49
P°0°	0·065
Org. N.	0·039

From the above Tables it would be evident that the soil was well drained sandy loam of moderate fertility and uniform texture. The *p*H was 7·5 and the total soluble salts present were 0·502 per cent.

RESULTS

As the location of the experiment in the year 1950-51 was different to that of the other three years, the analysis of data was carried out in two stages. Finally the data of three years (1951-54), analysed serially, were combined along with that of 1950-51 and the results obtained are summarised in the following Tables :

TABLE III(*a*)

Yield of individual years as well as average yield of grain for 1951-54 (md. per acre)

Treatment	1950-51	1951-52	1952-53	1953-54	Overall average for frequency of cultivation (1951-54)
A	13·60	4·68	18·07	10·44	11·06
B	19·87	7·17	20·35	11·31	12·94
C	26·90	9·07	22·99	14·04	15·36
D	27·05	8·59	24·27	12·54	15·13
Overall average for years	21·86	7·38	21·42	12·08	
S. Em (Treatments)	±0·74	±0·54	±0·29	±0·46	±0·30
C. D. 5 per cent	2·56	1·87	1·00	1·61	1·02
C. D. 1 per cent	3·88	2·83	1·51	2·43	1·54

S. Em. (for years 1951—54)	0·39
C. D. 5 per cent	1·54
1 per cent	2·00

A perusal of the results in Table III (*a*) reveals interesting facts. The difference between the frequency of cultivations in the individual years and also over the three years (1951-54) are highly significant. The yearly averages also differ significantly. The interaction of years with frequency of cultivation is also significant at 1 per cent level. It may be pointed out at this stage that a very severe hail storm occured in the month of March (1952) damaging badly all the treatments in 1951-52. Similarly, during the fourth year, the crop was uniformly and adversely affected by ' smut ' which reduced the yields considerably. The significance between years may, perhaps, be largely due to these calamities which were beyond experimental control.

With regard to the main effects of ploughing the results have indicated no significant difference among 'C' and 'D' treatments, but each of them was superior to 3 and 6 ploughings.

The yield obtained from treatment 'C' was the highest followed closely by 'D'. The additional ploughings over and above treatment 'C' caused a slight depression in grain yield suggesting that the optimum was reached at that stage and any effort beyond that minimum was a waste of time and money.

TABLE III (*b*)

Average yield of grain over the years as affected by the frequency of cultivation (*md. per acre*)

Treatments	Average over (1950-54)	Expressed as per cent over A	Difference over previous level of frequency	Additional yield per ploughing under different levels of frequency
A	11·70	100	—	—
B	14.67	125·4	2·97	0·99
C	18·25	156·0	3·58	1·19
D	18·11	155·1	—0·14	—0·04

From Table III(*b*) it will be observed that for each additional frequency over 3, response to the extent of 2·97 md. grain per acre was obtained up to 6 ploughings, and 3·58 md. per acre until 9 ploughings beyond which the yield was slightly depressed resulting in a loss of 0·14 md. grain. Information given in the last column regarding the response for additional ploughing is very interesting. For each additional ploughing over 3, response to the extent of 0·99 md. per acre up to 6 ploughings was obtained. Further increase in the frequency of ploughing till 9 gave an increased yield of 1·19 md. per ploughing per acre. It is evident from this, that

not only an increase in yield was effected but also the rate of increase became higher for each additional ploughing in this treatment as compared to increase in yield in 'B'. This was, however, not maintained with further addition in the number of ploughings.

Rather the yield depressed to the extent of 0·04 md. per ploughing with subsequent increase in the frequency. This again emphasises the importance of 9 ploughings indicating the optimum stage in the preparation of seedbed for wheat under the conditions prevailing in Delhi. The maximum frequency far from increasing the yield diminishes it.

TABLE IV

Yield of grain as affected by the application of ammonium sulphate' (in md. per acre)

Treatments	1950-51	1951-52	1952-53	1953-54	Overall average for nitrogen (1951-54)
N_0	19.42	6.08	20.02	12.61	12·40
N_1	24·29	8·67	22·82	11·56	14·35
S. Em (treatments yearwise)	±0·97	±0·33	±0·34	±0·39	±0·22
C.D. 5 per cent	2·98	1·02	1·04	'F' not sig.	0·69
1 per cent	4·18	1·43	1·45	,,	0·96

From Table IV it is clear that the nitrogen response is highly significant in the first three years and also the average response over three years. In the year 1953-54, because of the disease the significant response could not be had. It was higher in the first year as compared to other years. Taking the period as a whole, there was an increase of 2.30 md. per acre over N_0, the return per pound of nitrogen is rather low and this may be attributed to causes referred above.

TABLE V

Effect of weeding on grain yield (md. per acre)

Treatments	1950-51	1951-52	1952-53	1953-54	1951-54
W_0	21·72	6·12	21·01	11·06	12·73
W_1	21·85	8·48	21·70	11·70	13·96
W_2	21·99	7·52	11·70	13·49	14·19
S. Em (treatments yearwise)	±0·49	±0·13	±0·29	±0.49	±0·47
C. D. 5 per cent	'F' not sig.	0·38	'F' not sig.	1·40	0·66
1 per cent		0·53		1·86	0·85

It is evident from Table V that there was no significant difference between one and two weedings but both were significantly superior to no weeding.

Though the difference in yield due to weeding is highly significant, yet the increase has just been sufficient to defray the additional expenditure involved in the process, especially when the job is done with manual labour. One weeding in the early stage of the crop appears to be enough as weeds do not compete with the crop in the advanced stage of its growth.

It is observed that on a light soil with legume fodder preceding the main crop and high standard of farming the effect of weeds is not pronounced.

Interactions

The effect of interaction between cultivation and manuring is represented in Table VI

TABLE VI

Yield of grain per acre (average of 1951-54)

Treatments	N_0	N_1
A	10·09	12·04
B	12·33	13·55
C	14·71	16·02
D	14·47	15·78

S.Em = ±0·44

The interaction between the frequency of cultivation and nitrogen doses was not found to be significant. However, 9 and 12 ploughings with nitrogen dressing gave higher yield as compared to other ploughings.

TABLE VII

Yield of grain in md. per acre (average of 1951-52)

Treatments	W_0	W_1	W_2
A	10·58	11·24	11·37
B	12·52	13·19	13·10
C	13·96	15·91	16·22
D	13·85	15·48	16·05

S.Em±0·96 C.D.5 per cent 2·87, 1 per cent 3·64 'F' test sig. at 1 per cent level.

The interaction is significant. Highest yield was obtained with 9 ploughings and 2 weedings but the difference between 9 ploughings and 1 and 9 ploughings and 2 weedings is negligible. The effect of weeding unlike the effect of fertilizer was more pronounced in higher frequencies than the lower ones. It appears subsequent weedings do not make up the initial deficiency in the preparation of seedbed.

It may, therefore, be observed that the purpose of cultivation is more than the mere suppression of weeds.

Data relating to interaction between weeding and manuring are given in Table VIII.

TABLE VIII

Yield of grain per acre (average of 1951-54)

Treatments	N_0	N_1
W_0	12·09	13·37
W_1	13·16	14·75
W_2	13·46	14·91

S.Em=±0·22

The data show that the interaction here again is not significant.

DISCUSSION

Wheat is a cultivated crop and responds well to good tilth. It has been indicated that there are significant differences in the yield of grain as affected by frequency of cultivation. Highest yield has been obtained in treatment C, Table III (*b*) (18·25md.)

followed closely by treatment 'D' (18·11 md.). Treatment 'B' has given only 14·67 md. grain while treatment 'A' produced the lowest (11·70 md.). The trend is according to expectation save that the optimum was reached at 9 ploughings. Tillage being the costliest single item in arable farming should not be carried out according to the general belief that wheat responds to over-cultivation. Timely and just enough cultivation rather than the maximum cultivation should be the ideal.

The differences in the grain yield due to the differences in the frequency of cultivation were also observed by Hatcheson *et al.* [1917], Godel [1935], Lock *et al.* [1942], Sekhon [1947], Stewart [1947], Bartholomew [1948], Mitra [1949], Garg [1950], Khan and Mathur [1952] and Khan [1953].

The application of ammonium sulphate has resulted into highly significant increase in the grain yield. The higher yields of grain due to the application of ammonium sulphate were also obtained by Bledsoe and Skinner [1929], Russel and Watson [1940], Davis *et al.* [1940], Khan and Bhatnagar [1945], Hanway [1947], Black *et al.* [1947], and others.

The response to weeding like manuring has been highly significant though the increase in yield has not been considerable. The causes for this have already been discussed and it is doubtful whether the additional yield obtained is commensurate with the expenditure involved. The second weeding did not result in substantial return probably because at this stage the crop was sufficiently dense and vigorous to smother weeds. Any attempt to do weeding at this stage, appears to be harmful to the roots of plants and adversely affects the yield. This is in accordance with the findings of Keen [1942] and Wilcox [1946].

In regard to interactions the differences are not significant. It appears from the interaction between cultivation and manuring in Table VI that the highest and almost equal yields are obtained with CN_1. This is followed by DN_1, CN_0 and the lowest yield is obtained from AN_0. Three ploughings-*cum*-manuring have given almost equal yield to six ploughings alone ; while the difference between six ploughings plus manuring and 12 ploughings alone is of about one maund indicating that cultivation in excess of the optimum may prove harmful. The yields have been generally found to be higher (with and without manuring) under greater intensities of cultivation, the optimum of which is reached with 9 ploughings.

Treatments CW_1, CW_2 and DW_2 [Table VII] relating to cultivation and weeding have given about equal yields. The data also indicate that increasing the frequency of weeding beyond one is not economical. It is also observed that yields under the lower frequencies of cultivation inspite of proper weedings are lower than the higher frequencies. Obviously, therefore, the function of cultivation is more than mere removal of weeds.

It has been observed that the efficiency of fertilizer is considerably increased when the land is made free from weeds and the soil cap is removed by the operation of weeding thus promoting aeration.

Summary

A factorial experiment to find out the effect of 4 levels of frequency of cultivation [3, 6, 9 and 12] with or without fertilizer and weeding on the yield of wheat, N.P. 775, was conducted over a period of 4 years. The design of layout was split-plot, with 2 splits and 4 replications [4×2×3×4].

The difference in the frequency of cultivation resulted into highly significant variation in the yield. The findings show that the yield increases with the increase in frequency of cultivation up to a limit of 9 ploughings beyond which it falls. The response in yield was different for different levels of frequency.

The application of ammonium sulphate at 40 lb. N per acre increased the yield. The additional yield in terms of grain per acre was 2.30 md. over control.

The response to weeding was highly significant, but there was no significant difference between one and two weedings.

The gain is, perhaps, not big enough to defray the extra cost of operation especially when the job is done by hand.

It would be a poor economics for husbandman not to reduce tillage cost and cheapen production. Under Delhi conditions 9 ploughings should be considered as optimum.

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ROLE OF BERSEEM IN IRRIGATED AGRICULTURE

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BERSEEM (*Trifolium alexandrinum*) is commonly known as Egyptian clover. The home of berseem is Egypt and it is from this country that this plant travelled to other countries including India. The crop was first introduced and grown in India at the Government farm, Mirpurkhas, Sind in 1904. It was introduced at the Indian Agricultural Research Institute in about 1917.

Berseem in Egyptian agriculture

The role that berseem plays in agricultural economy of Egypt is very great. The entire cotton crop in about 2·0 million acres is grown after berseem. Without this crop, it is stated, it would not be possible to maintain the constant succession of crops under the great drain of perennial irrigation. The average yield of cotton obtained is the highest amongst the cotton growing countries in the world. It has been even possible to practice an intensity of 200 where ample facilities exist for irrigation. Berseem is said to feed the whole of the livestock of Egypt from November to June. Generally livestock is tethered in the crop.

Cultivation in India

In India, berseem is being grown for over 50 years and at this Institute over 30 years. Berseem can be sown in almost all types of soils. It is best sown in ploughed land which has been irrigated to a depth of 3-4 inches. The seed at the rate of 30 lb. per acre should be soaked for about 12 hours before sowing and broadcast in standing water or muddy conditions. In new lands where berseem is sown for the first time, the seed should be treated with berseem culture before sowing. The time of sowing is at the change between the end of hot and beginning of cold seasons, i.e. from end of September to end of October. It can be sown in standing cotton, maize, millets or in wet paddy lands provided in the latter case water will not remain stagnant very long.

Irrigation

The crop needs frequent irrigations to produce succulent and abundant material. The number of irrigations under Delhi conditions would be approximately 15, i.e. about 40 to 50 inches of irrigation.

Harvesting and yield

If sown in October, about six cuttings of berseem can be obtained by the end of April or early May. The first cutting gets ready after 6 to 8 weeks depending on the time of sowing. The subsequent cuttings get ready at intervals of 4 to 5 weeks and on an average 500 to 600 md. of green fodder per acre are obtained. There are instances when yields of over 1000 md. per acre have been obtained.

Utilisation of crop

It has been said that growing of berseem helps to build soil fertility, provides fodder for the cattle and feeding of berseem to milch cattle helps to increase yield of milk. The increase in milk yield of the cows when changed over to berseem ration is about 1 lb. per cow per day. The berseem green fodder is generally in excess during February and March and that it can be easily converted into silage or hay and fed in summer months. The analysis of green berseem, hay and silage is given in Table I.

TABLE I

Percentage on dry basis

	Ether extract	Crude protein	Carbo-hydrates	Food units	P_2O_5	CaO
Green berseem	3·44	21·2	37·5	89	0·6—0·80	2·0—2·5
Berseem hay	2·33	13·6	40·0	70	..	..
Silage	7·00	19·2	31·6	72	..	..

It will thus be seen that berseem whether fed to cattle in green, hay or silage form is a nutritive material for milch and draught cattle and its feeding helps to increase milk yield.

Improvement in yield by fertilization

The importance of berseem in Indian agriculture was soon realized and research work was started on this crop at this Institute in about 1940. Application of ammophosphate at the rate of 80 lb. P_2O_5 per acre has given optimum results with berseem. The manuring of berseem is economical and helps to increase its quantity and quality as can be seen from the results given in Table II.

TABLE II

The effect of fertilization with ammo-phosphate

Treatments	Av. yield of berseem green fodder in md. per acre	Net profit in rupees per acre over A	Chemical composition of berseem fodder (percentage on dry basis)		
			Nitrogen	P_2O_5	K_2O
A No manure	712·20	..	3·61	0·69	2·66
B Ammo-phosphate at 80 lb. P_2O_5 per acre.	897·70	66·70	3·93	0·86	2·63
'F' test	Significant				
SEm	±21·44				
C.D at 5 per cent	59·77				

For working out net profits, berseem green fodder is valued at Rs. 0·75 per maund and the value of 80 lb. of P_2O_5 in the form of ammonium phosphate has been charged at the rate of Rs. 0·90 per lb. of P_2O_5 which includes cost of application of the fertilizer.

Building up of soil fertility for crops in rotation

Several experiments have been conducted to study the effect of growing berseem on the building up of soil fertility. According to one authority a good crop of berseem adds 300 lb. of nitrogen per acre to the soil.

In berseem-paddy rotation at the Agricultural Research Sub-station, Karnal, the following results have been obtained in three experiments (Table III).

TABLE III

Treatments	Yield of paddy in md. per acre			
	Expt. I	Expt. II	Expt. III	Average
A No manure to paddy grown after berseem	38·4	35·50	35·90	36·6
B 40 lb. of nitrogen as sulphate of ammonia per acre to paddy grown after berseem	37·60	34·50	32·80	35·0

It will be seen that the addition of 40 lb. nitrogen as sulphate of ammonia to paddy grown after berseem has not helped to increase yield of paddy. It is, therefore, indicated that when berseem is the preceding crop, application of extra nitrogen to the succeeding crop, does not help materially to increase the yield of the crop over no manure.

In an area of 2·5 acres where berseem was grown in the previous winter season, yield of about 42·0 md. of wheat per acre was obtained with the application of 20 lb. nitrogen and 25 lb. P_2O_5 per acre as ammo-phosphate.

The above are few illustrations which indicate clearly the role of berseem in building up of soil fertility.

Wherever facilities exist for irrigation, it will be advantageous to introduce berseem in Indian agriculture. Its introduction would help to increase crop yield, build soil fertility, reduce cost of manuring, increase milk yield, provide succulent and nutritious fodder for cattle and reduce cost of maintenance of cattle.

INCIDENCE OF WIDESPREAD RAIN IN DIFFERENT SEASONS IN THE VARIOUS PARTS OF INDIA AND PAKISTAN

By K. L. Sinha

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(With 6 Text-Figures)

THE study of the different aspects of rainfall is of special interest to a country like India or Pakistan, that has to depend largely upon the rainfall for successful agriculture and from time to time is faced with excessive rain and floods resulting in great losses.

The rainfall that occurs in nature is on some occasions very localised and is confined to a few places only in an area, while on certain other occasions, it is widespread. The quantity of rain, collectively for the area, and also mostly for the individual stations, is generally greater in the case of widespread rainfall than in the case of localised rainfall. Again, because of its extent and intensity, widespread rain enables a large number of agriculturists to carry on with the different agricultural operations of ploughing, sowing, etc. Because of the extent and intensity, the widespread rain if it occurs successively over an area for a number of days, may cause floods in that or the adjoining areas if those areas lack suitable natural drainage system for quick removal of accumulated water. Widespread rain is, thus, an important aspect of the rainfall from different points of view—agricultural or otherwise.

Depending upon the field of activity in different seasons of the weather agents that are responsible for the occurrence of the widespread rainfall, the areas of widespread rainfall shift to different parts in the different seasons. It is proposed here to look into the seasonal distribution of the widespread rainfall in the Indo-Pakistan area and briefly discuss its features and the connected meteorological factors.

Rainy day for a station and widespread rain over an area

When the amount of the rainfall recorded at a station during the 24 hours is 10 cents, i.e. one-tenth of an inch, or more, the rainfall is considered to be significant and the day is taken to be a rainy day. If less than one-third of the stations in an area each records ten cents or more of rain in 24 hours, a few falls of rain are said to have occurred in that area, and if one-third to less than two-thirds of the stations record the rainfall, the rainfall is said to have occurred locally over the area. If, however, two-thirds or more of the stations in the area record the specified rainfall, it is taken to be widespread over the area. The above procedure is followed while describing the spatial distribution of the daily rainfall in respect of the different

meteorological divisions or subdivisions in the *Indian Daily Weather Reports*, published by the India Meteorological Department.

The above considerations lay stress more on the extent in space of the rainfall. No idea, however approximate, is obtained regarding the amount of rainfall except that the lower limit of the rainfall of the stations taken into account is at least ten cents in 24 hours, prescribed for a rainy day. The average amount of the rain on a rainy day for a station is, however, much higher than ten cents varying in the different parts with the seasons. Before presenting the statistics of the widespread rainfall, it may, therefore, be worthwhile to find out the average rainfall on a rainy day in the different seasons for places lying in the different parts of Indo-Pakistan, so that it may help in obtaining some idea about the average conditions with regard to the amount of rainfall also.

Average rainfall of a station on a rainy day in different seasons in different parts

Taking the meteorological features into consideration the year may be divided into four periods (i) the winter period covering the months of December to March, (ii) the pre-monsoon period of April and May, (iii) the monsoon period comprising the months of June to September, and (iv) the post-monsoon period of October and November. The average rainfall on a rainy day during the above periods and the year as a whole for a few selected stations are given in Table I ; Dibrugarh in the north-easternmost part of Indo-Pakistan, Pamban in the south, Srinagar in the north and Karachi in the west or north-west, and Bombay, Nagpur, Calingapatam and Lucknow in the intermediate areas have been chosen. These stations, lying in the different parts of Indo-Pakistan also lie in the different fields of activity of the south-west monsoon, north-east monsoon and the western disturbances. In addition to the above stations, Cherrapunji, which is dominated by its orographic features and which has its special importance as the highest rainfall recording station, has also been included in Table I.

From Table I, it would appear that leaving aside the heavy rain of the hill stations like Cherrapunji, the average rainfall on a rainy day for a station in the plains comes to about half an inch to three-quarters in the different parts of Indo-Pakistan during the winter and the pre-monsoon periods. During the south-west monsoon period, the average rainfall on a rainy day at a station remains about half an inch to three-quarters in the south-eastern parts of the Indian peninsula and the north-westernmost parts of Indo-Pakistan, but increases to three-quarters to one inch in the other areas. During the post-monsoon period when rainfall activity is more in the south-western parts of the peninsula due to the north-east monsoon, the average rainfall per day for a station there is about one inch, while it comes down to half an inch to three-quarters in the other areas. Taking the year as a whole, the average rainfall on a rainy day for a station is half an inch to three-quarters in the different parts of the Indo-Pakistan.

Seasonal distribution of widespread rain

The information regarding the widespread rainfall in the different meteorological subdivisions (Fig. 1 and Table 1A) of prepartitioned India has been collected from the daily weather reports published by the India Meteorological Department during the ten years from 1930 to 1939 and is presented here. The data collected are thus based only on the 300 daily weather reporting observatories There were, however, more than 3000 rainguage stations in India and for a detailed survey of the spatial distribution of rainfall, particularly with reference to each district as the area unit, it will be essential to consider the data of all the 3000 or more stations. As our present purpose is to make a rough general survey of the incidence of widespread rainfall over the much larger meteorological subdivisions, it may perhaps be attempted by considering the data from the much smaller number of weather reporting stations alone. The average number of days of widespread rainfall in the above four seasons for the various meteorological subdivisions are given in Table I and are depicted in Figs. 2 to 5 for ready pictures of the different features. Some features of the distribution of widespread rainfall in the different seasons in relation to the chief weather producing agents are discussed below.

TABLE I

Average rainfall on a rainy day in different seasons

Seasons	Dibrugarh	Pamban	Srinagar	Karachi	Bombay	Nagpur	Calingapatam	Lucknow	Cherrapunji
Winter period— (December—March)	0·43	0·64	0·45	0·45	0·60	0·48	0·73	0·45	0·71
Pre-monsoon period— (April-May)	0·73	0·57	0·45	0·67	0·81	0·42	0·65	0·51	1·97
South-west monsoon period— (June-September)	0·96	0·57	0·45	1·12	0·98	0·84	0·71	0·87	3·17
Post-monsoon period— (October—November)	0·61	0·91	0·41	0·23	0·74	0·70	1·17	0·65	1·79
Mean for the year	0·68	0·67	0·44	0·62	0·78	0·61	0·81	0·62	1·91

Winter period (December to March). Fig. 2 shows that Kashmir and the N.W.F.P. are the areas in this season having the highest number of occasions of widespread precipitation. Baluchistan on the western side and a belt of area from East Punjab extending east to south-eastwards through Uttar Pradesh also get comparatively higher number of days of widespread rainfall. In the South, southeast Madras is the area getting comparatively higher number of days of widespread rainfall.

The chief weather producing agents, in this season are the western disturbances which come over West Pakistan and India from further west and move in a east to north-east direction more frequently through the northern parts of West Pakistan and India in the beginning of the winter period and further south later on. These

disturbances are responsible for the predominance of the number of days of widespread precipitation in Kashmir, N.W.F.P., Baluchistan and the northern parts of India. In the South, occasional lows or low pressure waves moving in the reverse direction from east to west through the extreme south of the country or further south accentuate the activity of the northeast monsoon which continues over south-east Madras till the middle of December. In some years depressions or cyclonic storms also develop in December in the south Bay of Bengal and moving towards south-east Madras or Ceylon cause increased rainfall activity there. The occurrence of the widespread rain that takes place mostly in December in south-east Madras is due to the above causes.

Pre-monsoon period (*April and May*). Fig. 3. The areas of highest frequency of wide-spread rainfall lies in this season in the north-eastern parts and the south-western parts of India. A comparatively high number of days of widespread rainfall also lies in the extreme north in Kashmir and N.W.F.P.

The seasonal low pressure area which is over the sea in the winter period appears over land in this period over Chota Nagpur and neighbourhood. There is also relatively a low pressure area over the Peninsula. These cause in-draughts of moist air from the adjoining sea areas over the hot land, resulting in thunderstorm rain, sometimes widespread over the north-eastern and south-western parts of India. In some years one or two depressions or cyclonic storms from the Bay of Bengal or the Arabian Sea also increase the rainfall activity over these areas. The western disturbances which move towards the eastern parts of India are also directly or indirectly responsible for the occurrence of the severe thunderstorms, especially known as "Nor-westers" in Bengal. The frequency and intensity of the western disturbances moving through the northernmost parts of W. Pakistan and India are small as compared to those in the winter period and thus although N.W.F.P. and Kashmir record some days of widespread rainfall, their number is less compared to those in the winter period.

South-west monsoon period (*June to September*). There is a large increase both in the areas and number of days of widespread rainfall during the season. The areas of widespread rainfall are, however, predominantly (i) the west coast of the Peninsula, (ii) north-eastern parts of India, and (iii) central parts of India and adjoining areas. South-east Madras and West Pakistan and Kashmir represent the areas of very small number of days of widespread rainfall.

The rainfall in this season is due to the invasion of the great oceanic current, the south-east trade winds, which move northwards from the south of the equator and invades India as the south-west monsoon. The monsoon advances into India in two branches—the Arabian Sea branch and the Bay of Bengal branch. The Arabian Sea branch encounters in the west coast of the Peninsula the transverse barrier of the Western Ghats where it is forced to rise and give widespread rain. The Bay branch in the eastern side is interrupted by two rectangular mountain ranges of eastern Himalayas and the mountain ranges of Assam and Burma, and widespread rain results in the process. The high number of occasions of widespread rain in the

FIG. 1. Map showing meteorological divisions of India.

FIG. 2. Map showing number of days of widespread rainfall for different meteorological sub-divisions.

FIG. 3. Map showing number of days of widespread rainfall for different meteorological sub-divisions.

FIG. 4. Map showing number of days of widespread rainfall for different meteorological sub-divisions.

west coast of the Peninsula and the north-eastern parts of India are chiefly due to the orography of these areas.

The southerly Bay current interrupted by the high mountain ranges in the north-eastern side moves westwards up the Gangetic plains. The Arabian sea current surmounting the Western Ghats advances over the Deccan and the Central Provinces and generally meets the Bay of Bengal current along the line of trough of low pressure, which normally extends from Orissa to West Pakistan. Depressions occasionally form in the north of the Bay and move along this trough line and produce widespread rainfall along and near the track and particularly in the south-west sector. The third area of widespread rainfall in the central parts of India and the adjoining areas is due to the above causes.

It is interesting to see that although the west coast of the Peninsula gets widespread rainfall on a higher number of days than the north-eastern parts of India during the south-west monsoon period, floods are mostly reported from north-eastern parts during the south-west monsoon period and rarely from the west coast of the Peninsula. This appears to be due to the fact that the rain water swiftly moving down from the Western Ghats areas gets quick access to the Arabian sea due to the close proximity of the sea while the rain water entrapped in the Brahmaputra valley in the Assam, and neighbouring areas require considerable time to get free access to the Bay of Bengal.

Post-monsoon period (*October and November*). The Arabian Sea monsoon current retreats by successive stages southwards from Rajputana, Gujerat and the Deccan, and the Bay of Bengal current similarly down the Gangetic plains. As the monsoon retreats first from the north-western parts and later from the other parts, the occurrence of widespread rain becomes rare in the north-western parts in this season. The seasonal low, which lies over West Pakistan and adjoining north-west India in the monsoon season, disappears from there during the post-monsoon period and is transferred to the south Bay of Bengal, causing the north-east monsoon in south-east Madras and adjoining areas. Thus, whereas the rainfall activity in West Pakistan and the north-western parts of India is reduced to the minimum, the activity in respect of south-east Madras, which gets comparatively less rainfall during the south-west monsoon period itself due to the shielding effect of the Western Ghats, rises to its maximum at this time of the year. Some lows or low pressure waves moving in a east to west direction through the south Bay of Bengal at this time of the year occasionally increase the rainfall activity in the southern parts of the Peninsula. In some years cyclonic storms or depressions from the south Bay of Bengal, which recurve either in the Bay itself or near the east coast of the Peninsula, or through the south-east Arabian Sea and thence to the Peninsula, cause increased rainfall activity over the area extending north-eastwards from the Peninsula. The extent of space affected, however, depends upon the track of the storm of the depression.

Due to the combined effect of (i) the process of the retreat of the south-west monsoon (ii) setting in of the north-east monsoon, (iii) east to west movement of lows or low pressure waves through the south Bay of Bengal and (iv) invasion of the cyclonic storms or depressions from the south Bay of Bengal, the southern parts

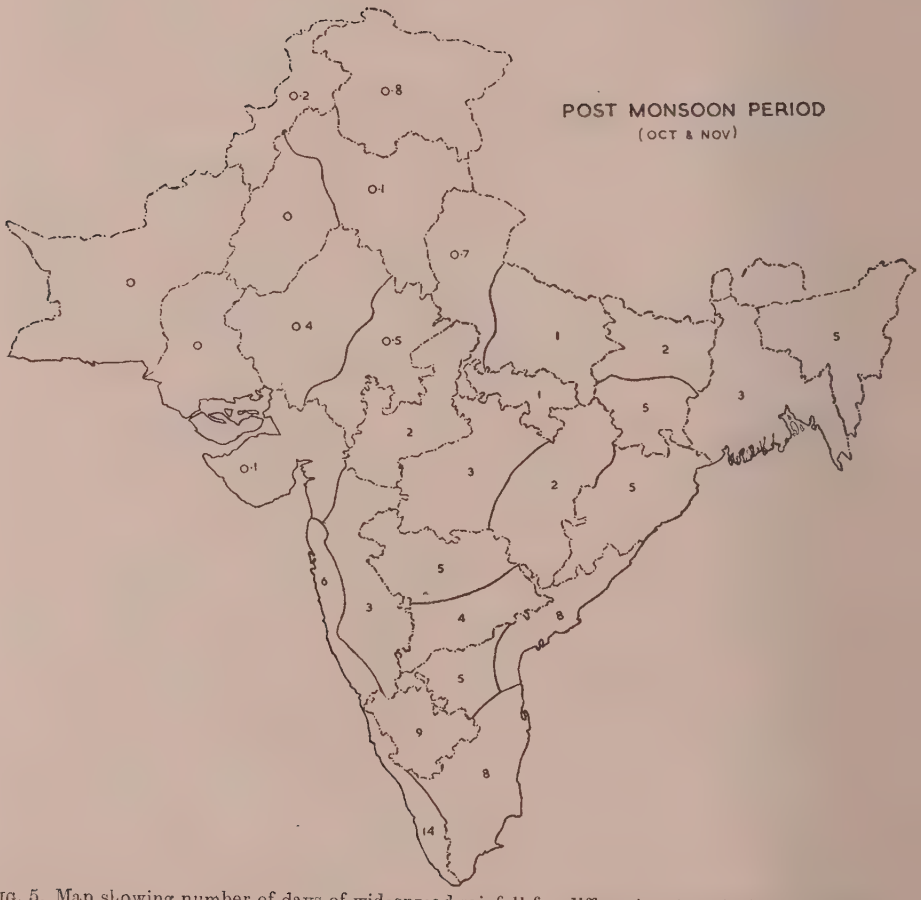

FIG. 5. Map showing number of days of widespread rainfall for different meteorological sub-division.

FIG. 6 Map showing number of days of widespread rainfall for different meteorological sub-division.

of the Peninsula is the area of highest incidence of widespread rainfall and the upper limit of the occurrence of widespread rain may be taken as the line passing in a south-west to north-east direction through the northern point of Konkan.

The distribution of the widespread rain for the year is shown in Fig. 6.

Widespread rain occurs more in winter period than the other periods of the year in the case of Kashmir, N.-W.F.P. and Baluchistan and in the post-monsoon period in the case of south-east Madras. South-west Punjab has as much widespread rainfall in the winter period as in the south-west monsoon period. The remaining meteorological sub-divisions have much more widespread rainfall in the south-west monsoon period than the other periods of the year. The frequency of widespread rain being predominantly large during the south-west monsoon period for most of the areas, the pattern of the annual distribution of the widespread rain is more or less like that of the monsoon period.

During the year, Sind gets the least number of days of widespread rainfall. Malabar, which gets widespread rain on a number of days during the south-west monsoon period, in the post-monsoon period and also in the pre-monsoon period, represents, on the other hand, the area of highest incidence of widespread rainfall during the year.

TABLE I-A

Number of days of widespread rainfall for various meteorological sub-divisions in different seasons

Sl. No.	Meteorological sub-division	Number of days of widespread rainfall				
		Winter period (Dec.-Mar.)	Pre-monsoon period (Apl.-May)	S.-W. monsoon period (June-Sept.)	Post-monsoon period (Oct.-Nov.)	Whole year
1	Assam	3·3	15·5	52·9	5.1	76·8
2	Bengal	0·3	3·9	44·4	3·1	51·7
3	Orissa	1·6	2·2	37·9	4·5	46·0
4	Chota Nagpur	4·3	2·5	46·4	4·6	57·8
5	Bihar	2·0	0·5	30·3	1·7	34·5
6	United Provinces, east	2·7	0·5	31·9	1·3	36·4
7	United Provinces, west	3·5	0·6	27·4	0·7	32·2
8	Punjab, east and north	4·9	0·7	11·7	0·1	17·4
9	Punjab, south and west	2·0	0·2	2·3	0·0	4·5

TABLE 1-A- *contd.*

Number of days of widespread rainfall for various meteorological sub-divisions in different seasons

Sl. No.	Meteorological sub-division	Number of days of widespread rainfall				
		Winter period (Dec.-Mar.)	Pre-monsoon period (Apl.-May)	S.-W. monsoon period (June-Sept.)	Post-monsoon period (Oct.-Nov.)	Whole year
1	2	3	4	5	6	7
10	Kashmir	9·7	4·2	2·2	0·8	16·9
11	N. W. F. P.	8·6	3·4	2·0	0·2	14·2
12	Baluchistan	3·9	0·2	0·0	0·0	4·1
13	Sind	0·6	0·0	1·6	0·0	2·2
14	Rajputana, west	1·2	0·8	8·5	0·4	10·9
15	Rajputana, east	0·2	0·3	15·0	0·5	16·0
16	Gujerat	0·1	0·2	12·8	0·1	13·2
17	Central India, west	0·6	0·2	33·1	1·7	35·6
18	Central India, east	2·3	0·6	28·7	1·1	32·7
19	Central Provinces, west	1·3	0·7	42·9	2·9	47·8
20	Central Provinces, east	1·2	1·2	38·1	2·1	42·6
21	Konkan	0·4	1·2	80·0	6·2	87·8
22	Bombay Deccan	0·3	0·5	14·2	2·8	17·8
23	Hyderabad, north	1·4	1·5	40·2	4·5	47·6
24	Hyderabad, south	0·6	1·0	19·8	4·3	25·7
25	Mysore	0·6	4·5	22·3	9·4	36·8
26	Malabar	0·9	9·8	71·9	13·9	96·5
27	Madras, south-east	2·7	1·1	1·0	8·4	13·2
28	Madras, Deccan	0·4	1·9	11·8	5·0	19·1
29	Madras coast, north	0·4	0·7	9·8	8·1	19·0

OCCURRENCE OF A VIRUS CAUSING DISTORTION IN TOBACCO

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(With 4 Text-Figures)

DURING the course of a survey for plant virus diseases in 1953 in Simla Hills, tobacco plants were found infected with mosaic diseases, showing marked differences in symptoms. Samples of mosaic affected tobacco plants were collected from several localities in Simla Hills and eight virus cultures were established in the laboratory on suitable host plants by means of sap-inoculation. Preliminary investigations on identification of the causal viruses showed the presence of the common tobacco mosaic virus (Nicotiana virus I) in two cultures, whereas, in other two cultures it was found present in mixture with an unidentified virus. The remaining four cultures did not show the presence of the tobacco mosaic virus at all.

Detailed investigations were undertaken on one of the cultures showing mixed infection, with a view to determine the identity of the component other than the tobacco mosaic virus.

Experimental

All investigations were conducted in an insect-proof glass-house. While making sap-inoculations carborundum powder was invariably used as an abrasive.

Isolation of the virus

It was found that sap-inoculations on *Nicotiana glutinosa* L. from the diseased tobacco plants first produced local necrotic lesions, typical of *Nicotiana* virus I, on inoculated leaves which were gradually shed off, and subsequently, incited a severe systemic infection in the new leaves. Inoculations were made separately from leaves showing local lesions and the new leaves exhibiting only systemic symptoms. In case of the inoculum taken from the leaves showing local lesions characteristic symptoms of the original culture were reproduced, whereas, in the inoculations made from the new leaves showing only systemic infection no local lesions were produced on *N. glutinosa*. Thus, the other component virus was filtered out from the mixture by passage through *N. glutinosa* and a pure culture was established for study. In repeated serial transfers the virus was found to produce only systemic infection in *N. glutinosa* without producing local lesions at any stage.

Transmission

The virus was easily transmissible by sap-inoculation as well as by grafting. It was not seed-borne which was determined in case of *N. glutinosa* by testing about 500 seedlings raised from seeds collected from severely diseased plants.

Host-range

The virus was successfully transmitted by sap-inoculation to *Nicotiana tabacum* L. vars. White Burley and Harrison's Special, *N. glutinosa* L., *N. longiflora* Cav., *N. paniculata* L., *N. companulata*, *N. affinis* T. Moore, *N. rustica* L., *N. sanderae* Hort., *N. langsdorffii* Weinm., *Datura alba* Nees. (probably same as *Datura inoxia* Mill.), *D. metel* L., *Petunia hybrida compacta* Vilm. var. Rosy Morn, *Physalis peruviana* L., *Nicandra physaloides* (L.) Pers., *Solanum nigrum* L., *Lycopersicon esculentum* Mill., and *Nierembergia frutescens*. The symptoms produced on some of the important hosts are briefly described :

Nicotiana tabacum. About 12 days after inoculation the White Burley tobacco plants showed pronounced vein-clearing of the young leaves followed by severe mottle, persistent green vein-banding and appearance of deep green blisters. In advance stages, the leaves became variously malformed with their tips and margins curled downwards. Sometimes, the lamina was much reduced in size (Fig. 1). No local lesions or ring spots were produced at any stage. The reaction on Harrison's Special tobacco was slightly mild as compared to the variety White Burley.

N. glutinosa. After 5-6 days of inoculation the leaves showed vein-clearing followed by arresting of apical growth and deformity of new leaves which were severely malformed and, sometimes, the lamina was reduced, partly or wholly, to the mid rib (Fig. 2). The symptoms were more severe in plants which had been inoculated in very young stage and such plants did not continue their normal growth after infection. However, when older plants were inoculated they only showed intense vein-clearing and slight curling of young apical leaves.

Inoculations from macerated roots taken aseptically from diseased plants always gave positive infection, thus showing the presence of the virus in infectious state in the roots of *N. glutinosa*. However, there was apparently no difference in the appearance of diseased roots as compared to the healthy ones. Though the presence of the virus in plant roots has been reported in quite a few other cases, this aspect has not been investigated in respect of a large number of plant viruses known [Fulton, 1941].

N. rustica. The leaves showed deep green blistering mottle, waviness of margins, and slight puckering and deformity.

N. companulata. Pronounced vein-clearing was followed by blistering mottle accompanied by puckering of leaves, and severe grass blade effect, so much so that some of the leaves developed only into tendril-like structures (Fig. 3).

N. langsdorffii. Intense vein-clearing was followed by a severe dark green mottle accompanied occasionally by puckering and slight malformation of leaves.

FIG. 1. Plant of *Nicotiana tabacum* var. White Burley showing vein-clearing, severe mottling, puckering and malformation of leaves.

FIG. 2. Plant of *Nicotiana glutinosa* showing severe malformation of leaves.

Lycopersicon esculentum. The new leaflets showed a fleeting, light green mottle and, in severe cases, became narrow and slightly curled downwards, without any puckering.

Solanum nigrum. Severe blotchy mottle and puckering of leaves were produced.

Physalis peruviana. The new leaves showed intense vein-clearing followed by severe pale interveinal mottle and vein-banding.

Datura alba. Intense vein-clearing was followed by a severe blistering and blotchy mottle. The leaf margins were wavy and curled upwards. The lamina was severely malformed and occasionally showed, in part or whole, grass blade effect. Fig. 4 shows the symptoms on this host.

Datura metel and *Nierembergia frutescens*. No apparent symptoms were observed on *D. metel* (both purple and green stemmed varieties were tested) and *N. frutescens*. But the virus was carried symptomlessly which was repeatedly confirmed by back-inoculation tests.

All efforts to transmit the virus by sap-inoculation as well as by grafting to *Nicotiana glauca* R. Grah., *Solanum melongena* L., *S. nodiflorum* Jacq., *S. tuberosum* L. vars. President, Majestic, and Up-to-date, *Datura stramonium* L., *Capsicum frutescens* L. var. *longum* Bailey (Chilli, Syn. *C. annuum* L.), *C. frutescens* L. var. *grossum* Bailey (Sweet pepper), in Solanaceae, remained unsuccessful. The virus could also not be transmitted by sap-inoculation to *Brassica oleracea* L. var. *Capitata* L., *B. campestris* L. var. *sarson* Prain, *Hesperis matronalis* L., *Alyssum maritimum* Lam., *Cucumis sativus* L., *Phaseolus vulgeris* L., *Lathyrus odoratus* L., *Cyamopsis tetragonoloba* (L.) Taub., *Callistephus chinensis* Nees., *Chrysanthemum* sp., *Dahlia* sp., *Gomphrena globosa* L., *Vinca rosea* L., and *Dianthus* sp. The inoculated plants neither developed any symptoms nor the virus could be recovered from them on sub-inoculation to *N. glutinosa*.

Properties of the virus

All tests were made on young plants of *N. glutinosa* which was found to be the most suitable indicator plant. The infective sap for various tests was also invariably obtained from diseased *N. glutinosa* plants.

Thermal inactivation. The virus was inactivated by ten minutes exposure between 72° and 78°C.

Dilution end point. The undiluted leaf extract from diseased plants of different ages was found to loose infectivity at dilutions within the range of 1 : 60 to 1: 200. In eight tests out of nine, the virus was found to withstand dilutions up to 1 : 80 but not 1 : 150.

Longevity in vitro. Standard extract (1 gm. young infected leaves ground up in 1 c.c. of water in a pestle and mortar and juice pressed out through muslin was stored at room temperature (range 12°C.—19°C.) and tested at intervals of 24 hours for infectivity. It was found that the virus started losing infectivity after about

FIG. 3. Plant of *Nicotiana campanulata* showing blistering-mottle and puckering of leaves. Some leaves have been reduced to tendril-like structures.

FIG. 4. Plant of *Datura alba* showing severe blotchy mottle and malformation of leaves.

192 hours of storage as shown by lesser percentage of the test plants infected, and was rendered completely innocuous after 240 hours of storage. Also, no difference was obtained when the infective sap was stored after it had been centrifuged at 3,000 r.p.m. for 30 minutes.

Effect of chemicals. Standard extract was centrifuged at 3,000 r.p.m. for 15-20 minutes. Equal volume of the reagent to be tested was added to the supernatant and the mixture shaken vigorously. Inoculations were made on test plants after intervals of 15, 30, 60, 90, and 120 minutes. The inoculated leaves were thoroughly washed with distilled water immediately after inoculation.

The virus was inactivated within 15 minutes of its contact with absolute ethyl alcohol, but could withstand 50 per cent alcohol for one hour and occasionally up to two hours. In another series of tests, an equal volume of absolute ethyl alcohol was added to the centrifuged standard extract and the mixture again subjected to centrifugation at 3,000 r.p.m. for about ten minutes. Inoculations were made separately from the supernatant as well as from the precipitate washed and dissolved in a small quantity of water. No infection was obtained in either case. The latter series of tests were conducted to determine whether it was merely the presence of alcohol which inhibited infection or the actual inactivation of the virus.

The virus also lost infectivity when allowed to stand for 15 minutes with HNO_3 (1 : 200), HCl (1 : 200), NaOH (0·5 and 1·0 per cent solutions), and H_2O_2* (undiluted and 1 : 2 dilution). It was not inactivated after remaining in contact with formalin (1 : 200) for one hour. Further, it was indicated that the virus could withstand 50 per cent glycerine and 0·5 per cent carbolic acid but not acetone, for one hour.

Discussion

The virus under report is characterised by a very low dilution-end-point (1 : 80-1 : 150) coupled with a longevity *in vitro* of about 216-240 hours and thermal-inactivation between 72-78°C.

Its host range is restricted to solanaceae. It incites severe systemic infection in tobacco and *N. glutinosa*, besides other hosts. Though the virus was successfully transmitted to nine *Nicotiana* species, it failed to infect *N. glauca*. A few tobacco viruses have been reported in literature which do not infect *N. glauca* including the one described by McKinney [1931], but none resemble the virus under report in symptomatology or other characteristic properties. In causing systemic infection in *N. glutinosa* and a few other properties it appears to resemble *Nicotiana* viruses 3 and 4 which are also systemic in this host [Smith, 1937]. However, *Nicotiana* virus 3 (Syn. Mild Tobacco Mosaic Virus Johnson) produces a mild mottle on tobacco, is transmissible to potato and chilli, and has a thermal-inactivation point of 60°C. [Johnson, 1927] ; *Nicotiana* virus 4 (Syn. Tobacco Bleaching Mosaic

* Commercially available hydrogen peroxide containing 6 per cent H_2O_2 by weight equivalent to 20 vols. of Oxygen was used.

Virus Johnson) is transmissible to *N. glauca* besides potato and chilli, has a longevity *in vitro* of about 3 days, and is inactivated by 1 : 200 nitric acid in one day [Johnson, 1927] ; whereas, the virus under report produces a very severe mosaic and malformation of leaves in tobacco, is not transmissible to potato, chilli or *N. glauca* by sap-inoculation as well as grafting, can withstand storage *in vitro* up to 9 days, is inactivated by exposure to 1 : 200 nitric acid within 15 minutes, and its thermal-inactivation is above 72°C. Further, *Nicotiana* viruses 3 and 4 have been identified as strains of cucumber mosaic virus [Valleau, 1940 ; Anon. 1946], whereas, the virus reported herein is not transmissible to any host outside *Solanaceae* including cucumber.

It is, therefore, evident that the virus under report is different from *Nicotiana* viruses 3 and 4. It also does not resemble other viruses recorded in literature naturally occurring on tobacco or transmissible to it of which any details are available.

A virus designated as *Datura* virus 3 has been reported from India by Capoor and Varma [1952] which produces similar symptoms on *Datura alba* as the virus under report. However, the two viruses are quite different as shown by their properties.

It is, therefore, considered that the virus under report is a new record and the name Distortion mosaic of Tobacco is proposed.

Summary

A virus isolated from a tobacco mosaic complex by filtration through *Nicotiana glutinosa* has been investigated.

The host range of the virus is restricted to *Solanaceae*. It causes a severe systemic disease in *Nicotiana tabacum* and *N. glutinosa*. It is transmissible to seven other *Nicotiana* sps. but not to *N. glauca*, and is carried symptomlessly in *Datura metel* and *Nierembergia frutescens*. It has a dilution-end-point between 1 : 180-1 : 150, longevity *in vitro* of about 9 days, and a thermal-inactivation-point between 72-78°C.

The virus appears to be different from any of the viruses, hitherto, recorded on tobacco and is considered to be a new record.

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PRELIMINARY STUDIES ON BANANA FRUIT DEVELOPMENT

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(With 9 Text-Figures)

EDIBLE bananas are vegetatively parthenocarpic and effectively seed sterile and the fruits develop without the stimulus of pollination. Vegetative parthenocarpy is believed to be due to production of hormones in the ovary and fruit [Simmonds, 1953]. Simmonds defines parthenocarpy as the potentiality for development of a seedless fruit which may or may not be seeded if pollinated. Parthenocarpy is always associated with some degree of seed sterility and it is known to be controlled by a complex of genetical and cytological factors. The preliminary investigations on the development of the banana fruit are undertaken mainly to study the rate of development of the fruits of some of the important commercial varieties and have no bearing on cytogenetical factors but are purely complimentary to the metabolic activities of the fruits of the varieties concerned.

Material and Methods

Six uniform sized plants in each of the two important commercial varieties *Poovan* and *Monthan* were selected for these studies. Soon after the opening of the second hand a group of six ovaries from the middle nodal cluster of flowers was taken for measurements. Weekly measurements of length and girth of the selected fruits were taken from the date of opening of the second hand to the full maturity stage indicated by the commencement of ripening of any single fruit or more in the bunch before harvest. For the measurement of length three to four surface cuts were made at intervals on the rind of the fruit with a pin-point and the lengths measured were added up to get the total length of the fruit in millimetre. Circumference was measured in millimetre with a twine around the thickest portion of the fruit. It has been observed that there is practically no difference in the rate of development of the fruits in the first and second hand of the bunch. The banana bunch from the time it is shot out to the harvesting stage takes about 14 to 17 weeks [Nayar, 1950]. So volume in cc. and weight in grams were recorded from the tenth week onwards for the fruits from the first hand. Fruit volume was measured by displacement of water. Weekly measurements of volume and weight were recorded for three fruits detached every week from the first hand of the bunch from the tenth week onwards up to the fully mature stage. Though this method is admittedly liable to subjective errors, it gives fairly reliable data indicating the trend of development which is well

correlated with other linear measurements. Growth curves were constructed from weekly measurements of length, circumference, volume and weight. The growth is normally measured along the vertical axis and the time along the horizontal one. In the case of growth curves the vertical scale may show (i) the actual growth and (ii) the relative growth (the Napierian Logarithm of the actual growth measurement is *loga*). In the case of increment curves the vertical scale may show (i) the absolute increment and (ii) the relative increment. For the data under study, the measurements of which were taken at regular weekly intervals, the rate of increment is equal to the absolute increment and it represents the average rate of growth during any particular time interval. The relative increment takes into account not only the time factor but also the size of the individual for which each increase is recorded.

The increment curves will be irregular in character when the data are subject to unavoidable variation. In such cases only the growth curves can provide a better indication of the nature of growth.

For the data under study, the growth curves (1. actual and 2. relative growth curves) were constructed from weekly measurements of length, circumference, volume and weight in the case of both the varieties *Poovan* and *Monthan*. Increment curves were constructed wherever necessary.

Results and Discussion

(*a*) *Development of the fruit of the variety* Poovan

The development of the fruit of the variety *Poovan* in respect of length and circumference (or girth) gradually attains almost the maximum by about the eleventh and twelfth week respectively from the time of opening of the hands (Fig. 1-*a* and 2 ; Table I-*a* and I-*b*). But the relative increment percentage of length is greatest during the second week of development of the fruit and girth during the first week of development (Fig. 1-*b* ; Table I-*a* and I-*b*). From the twelfth week onwards the relative growth in respect of length and circumference is comparatively little. After the twelfth week there is also a decline in the relative growth in respect of weight and volume of the fruit. The fruit bunch of the *Poovan* variety comes to harvest during the sixteenth week, after attaining full maturity. If the bunch is harvested a week earlier (i.e., during the fifteenth week) the relative percentage loss in weight over the total weight is 3·36 per cent ; if harvested two weeks earlier that is, during the fourteenth week, the percentage of loss over the total weight is 12·76 ; likewise the percentage of loss for harvests during three weeks and four weeks prior to full maturity are 22·36 and 32·40 per cent respectively (Table I-*c*). This means that about a third of the weight of the bunch is lost if the harvest is done one month before maturity. Harvest of immature *Poovan* bunches is extensively practised by banana merchants and their middlemen for all bunches booked by rail to Madras, Mysore, Bangalore, Olavakkot, Coimbatore and Mettupalayam from the banana areas in Tanjore and Trichinopoly districts. The estimated requirement of *Poovan* fruits for Madras city alone is about 800 railway maunds per day. All these bunches

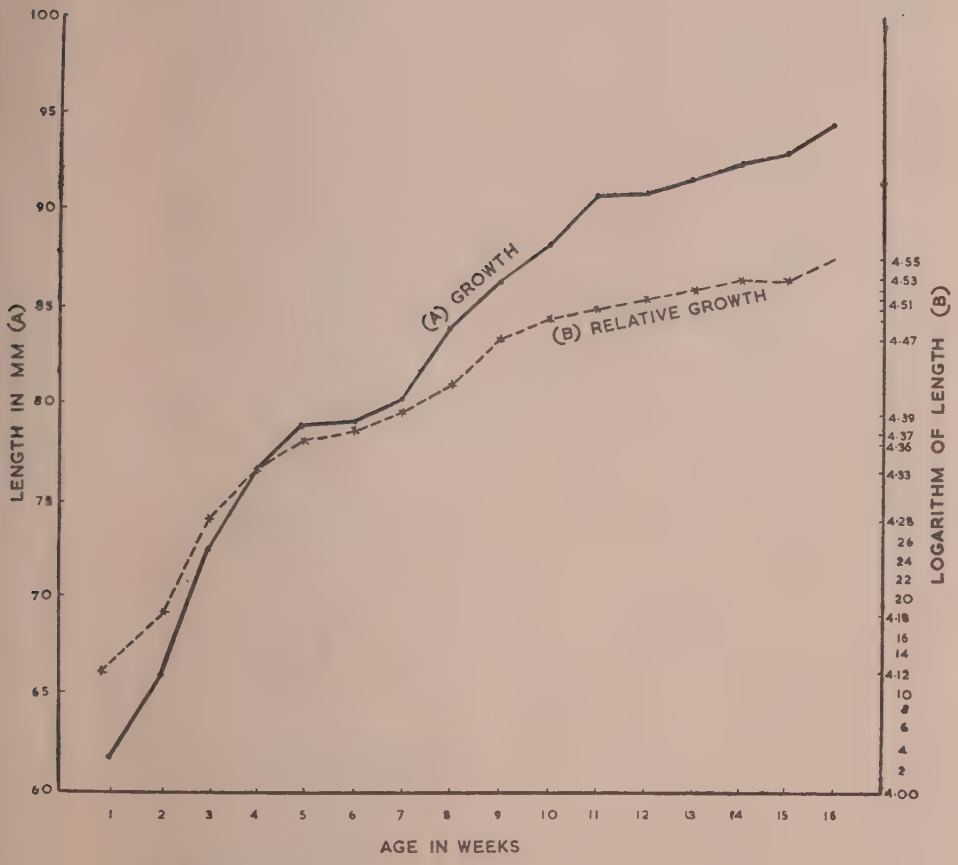

Fig. 1-*a*. Growth curves for the variety *Poovan* in respect of length.

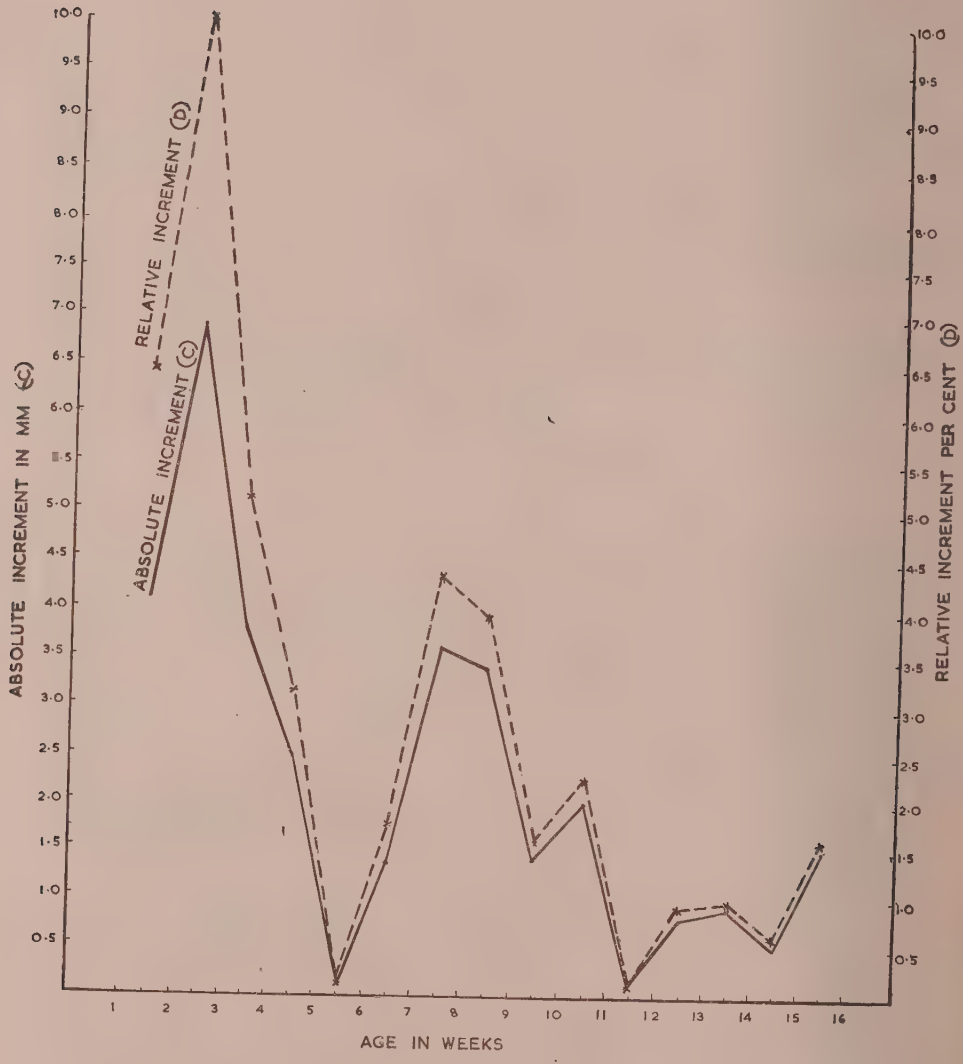

FIG. I-*b*. Increment curves for the variety *Poovan* in respect of length.

FIG. 2. Growth curves for the variety *Poovan* in respect of girth.

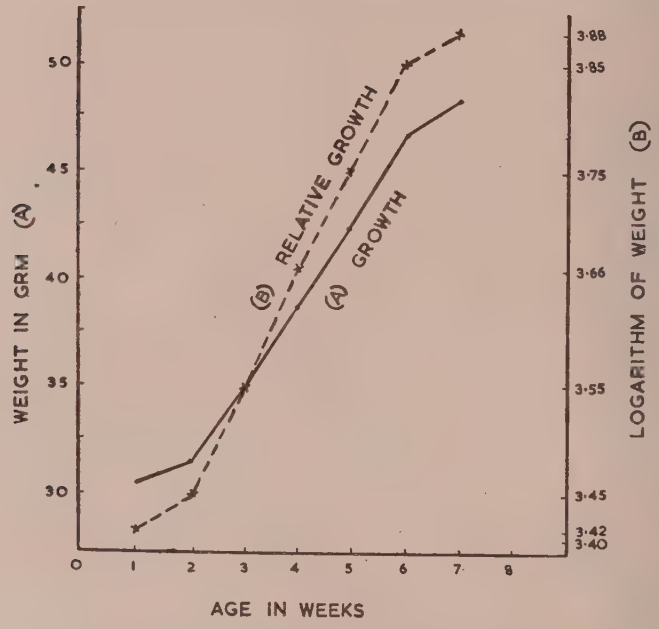

FIG. 3. *Poovan* growth curves in respect of weight.

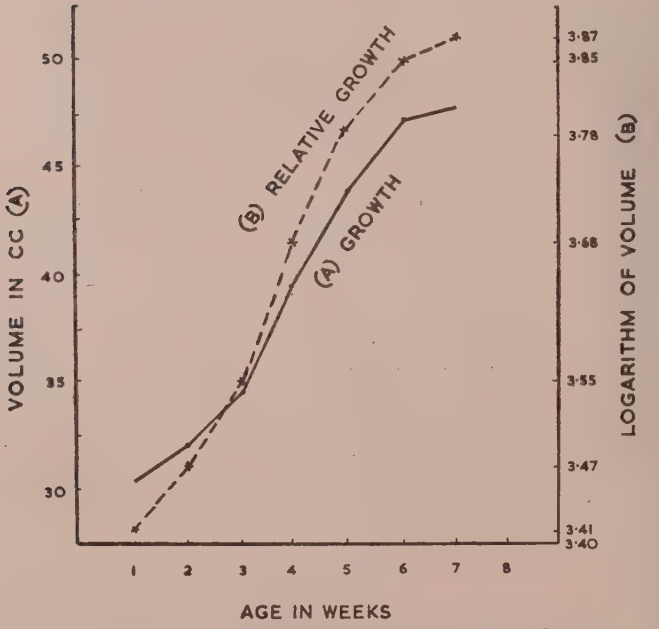

FIG. 4. Growth curves for the variety *Poovan* in respect of volume.

TABLE I-*a*

Weekly length measurements of the Poovan *variety*

Age of the developing fruit in weeks	*Length in mm.	Rate of increment in mm. per week	Napierian logarithm of length	Relative increment of length per week
1	61·6		4·1207	
		4·1		6·44
2	65·7		4·1851	
		6·9		9·99
3	72·6		4·2850	
		3·8		5·10
4	76·4		4·3360	
		2·4		3·09
5	78·8		4·3669	
		0·1		0·13
6	78·9		4·3682	
		1·4		1·76
7	80·3		4·3858	
		3·6		4·38
8	83·9		4·4296	
		3·4		3·98
9	87·3		4·4694	
		1·4		1·59
10	88·7		4·4853	
		2·0		2·23
11	90·7		4·5076	
		0·1		0·11
12	90·8		4·5087	
		0·8		0·87
13	91·6		4·5174	
		0·9		0·98
14	92·5		4·5272	
		0·5		0·54
15	93·0		4·5326	
		1·5		1·60
16	94·5		4·5486	

*Mean of 36 measurements.

TABLE I-*b*

Weekly measurement of circumference (girth) of Poovan *variety*

Age of the developing fruit in weeks	*Girth in mm.	Rate of increment in mm. per week	Napierian logarithm of girth	Relative increment per cent of girth per week
1	53·2		3·9741	
2	62·6	9·4	4·1368	16·27
3	69·1	6·5	4·2356	9·88
4	72·7	3·6	4·2864	5·08
5	75·0	2·3	4·3175	3·11
6	78·9	3·9	4·3682	5·07
7	79·2	0·3	4·3720	0·38
8	72·9	3·7	4·4176	4·56
9	85·8	2·9	4·4520	3·44
10	90·4	4·6	4·5043	5·23
11	93·1	2·7	4·5337	2·94
12	95·3	2·2	4·5570	2·33
13	95·6	0·3	4·5602	0·32
14	96·2	0·6	4·5664	0·62
15	98·9	1·7	4·5941	2·77
16	100·1	1·2	4·6062	1·21

*Mean of 36 measurements.

TABLE I-*c*

Weekly measurement of weight of Poovan *variety*

Age of the developing fruit in week	*Weight in grams	Increment rate per week	Napierian logarithm of weight	Relative increment per cent of weight per week
10	30·5		3·4177	
		1·1		3·55
11	31·6		3·4532	
		3·3		9·23
12	34·9		3·5525	
		3·8		10·34
13	38·7		3·6569	
		3·9		9·60
14	42·6		3·7519	
		4·2		9·40
15	46·8		3·8459	
		1·6		3·36
16	48·4		3·8795	

*Mean of 18 measurements.

TABLE I-*d*

Weekly measurement of volume of Poovan *variety*

Age of the developing fruit in week	*Volume in cc.	Rate of increment in cc. per week	Napierian logarithm of volume	Relative increment per cent of volume per week
10	20·4		3·4145	
		1·7		5·44
11	32·1		3·4689	
		2·6		7·79
12	34·7		3·5468	
		4·9		13·20
13	39·6		3·6788	
		4·1		9·86
14	43·7		3·7774	
		3·5		7·70
15	47·2		3·8544	
		0·6		1·26
16	47·8		3·8670	

*Mean of 18 measurements.

are harvested by judging on the appearance of the fruit, at least ten to fifteen days prior to maturity. Even working on a 10 per cent loss in weight, the estimated loss of fruits per year in Madras city alone works out to 28,800 railway maunds. The loss must be colossal when all the consuming centres are taken into consideration. Retailers do not insist on fully mature bunches for sale, as ripening is no problem for them, all the bunches being artificially ripened by smoking. Correct knowledge of maturity of the fruits is essential for profitable cropping and marketing of the fruit. Stamping the date of emergence of the bunch on the peduncle as done in some foreign countries like Canary Islands and grading may be useful to reduce loss by weight of banana bunches due to immature harvest. For the *Poovan* variety, harvest of bunches of less than fifteen weeks, duration from opening of the first hand result in appreciable loss to the grower.

(*b*) *Development of the fruit of the* Monthan *variety*

The development of the fruit of the *Monthan* variety in respect of length and girth is in the form of an ascending curve indicating that the age of the fruit on the bunch is directly proportionate to the increment in length or girth of the developing fruit in a given period (Fig. 5 and 6, Table II-*a* and II-*b*). The relative increment percentage of length and girth is maximum as soon as the hands are open and the ovaries start their initial development (Table II-*a* and II-*b*). Obviously there is little early growth check in the development of the fruit of the variety *Monthan* It may also be noted that the relative increment percentage of weight and volume attains another peak period during the thirteenth week of fruit development in the case of the *Monthan* variety (Fig. 7 and 8). Afterwards the decline in the relative growth is quite perceptible. As in the case of the variety *Poovan*, the fruit bunch of *Monthan* also comes to harvest during the sixteenth week after full maturity. If the bunch is harvested a week earlier (i.e., during the fifteenth week) the total loss in weight is 2·68 per cent. But if harvested during the fourteenth week the percentage of loss over the total weight will be 9·14. Similarly, the percentage of loss for harvests during the thirteenth and twelfth weeks are 23·07 per cent and 25·90 per cent respectively, over the total weight (Table II-*c*). *Monthan* being essentially a culinary variety, the bunch is usally harvested immature by about the eleventh to twelfth week after flowering. The consumers prefer not to have fully mature fruits for cooking. The loss of fruit weight for a variety which is mostly consumed locally is, therefore, considerable. The optimum stage of harvest of the bunch of the *Monthan* variety purely for culinary purposes will be during the fourteenth week after flowering. In and around Kumbakonum and Mayuram talukas of Tanjore district *Monthan* is also used as a dessert fruit by the working classes. If the fruits of the *Monthan* variety are desired for dessert purposes it will be very advantageous to harvest the bunches during the fifteenth week when the relative percentage loss over the total weight be the minimum, i.e., only 2·68 per cent.

Fruit development in bananas has definite relation to the numerous cytological and genetical complexities like ploidy, hybridity, chromosomal changes, etc.

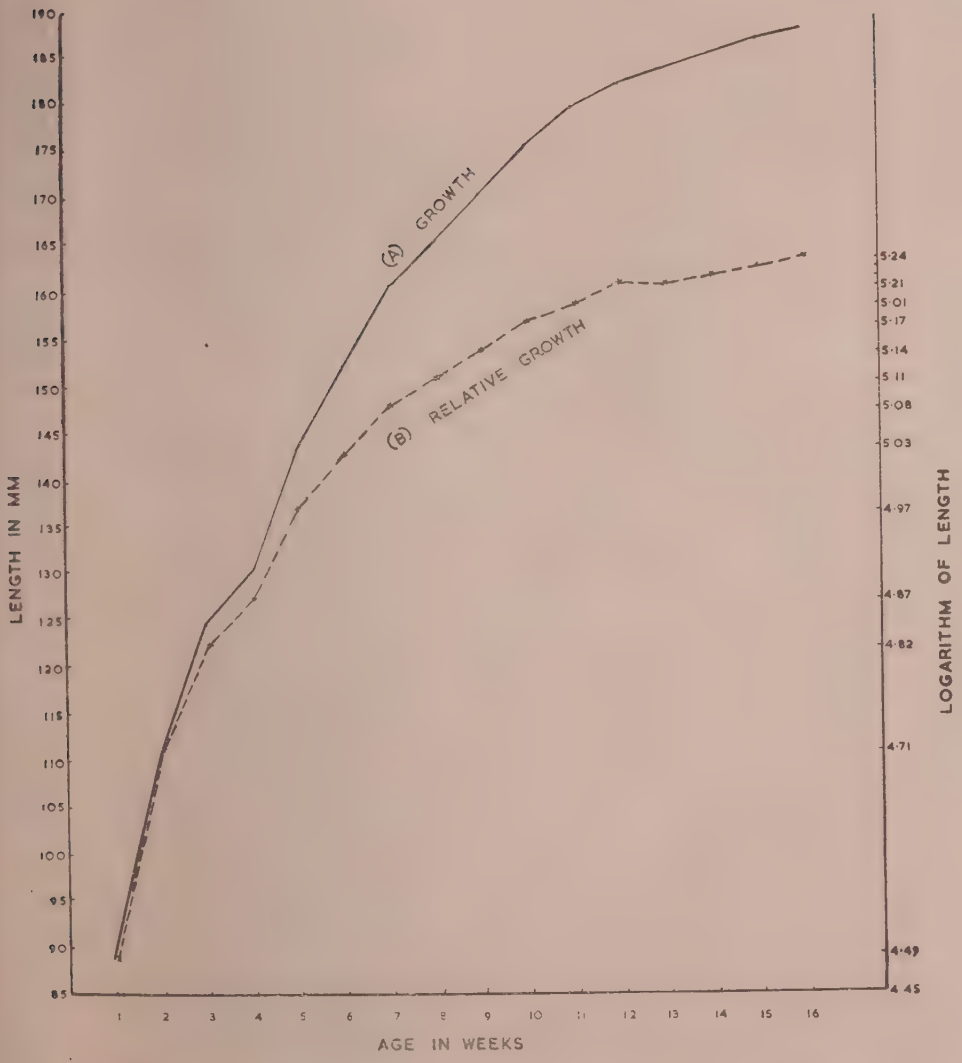

Fig. 5. Growth curves for the *Monthan* variety in respect of length

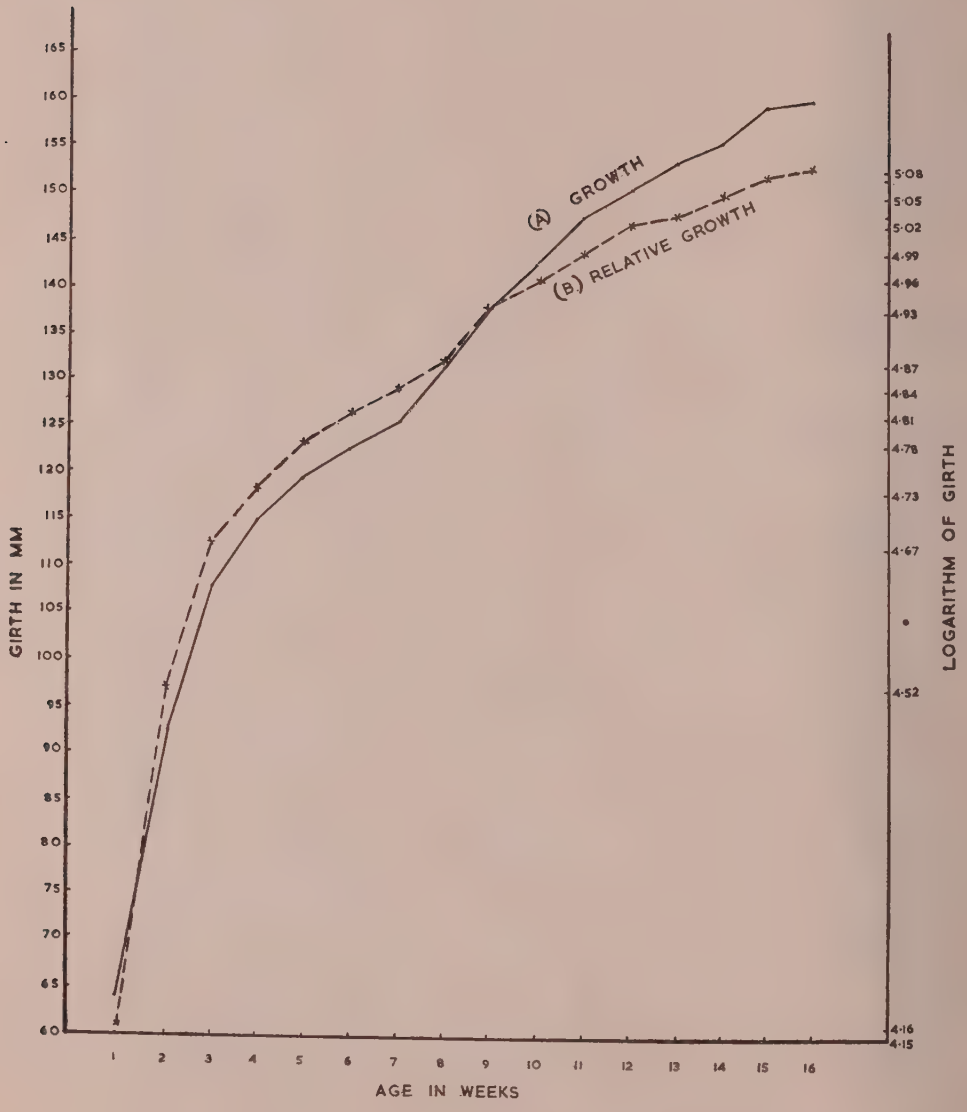

FIG. 6. Growth curves for the *Monthan* variety in respect of girth

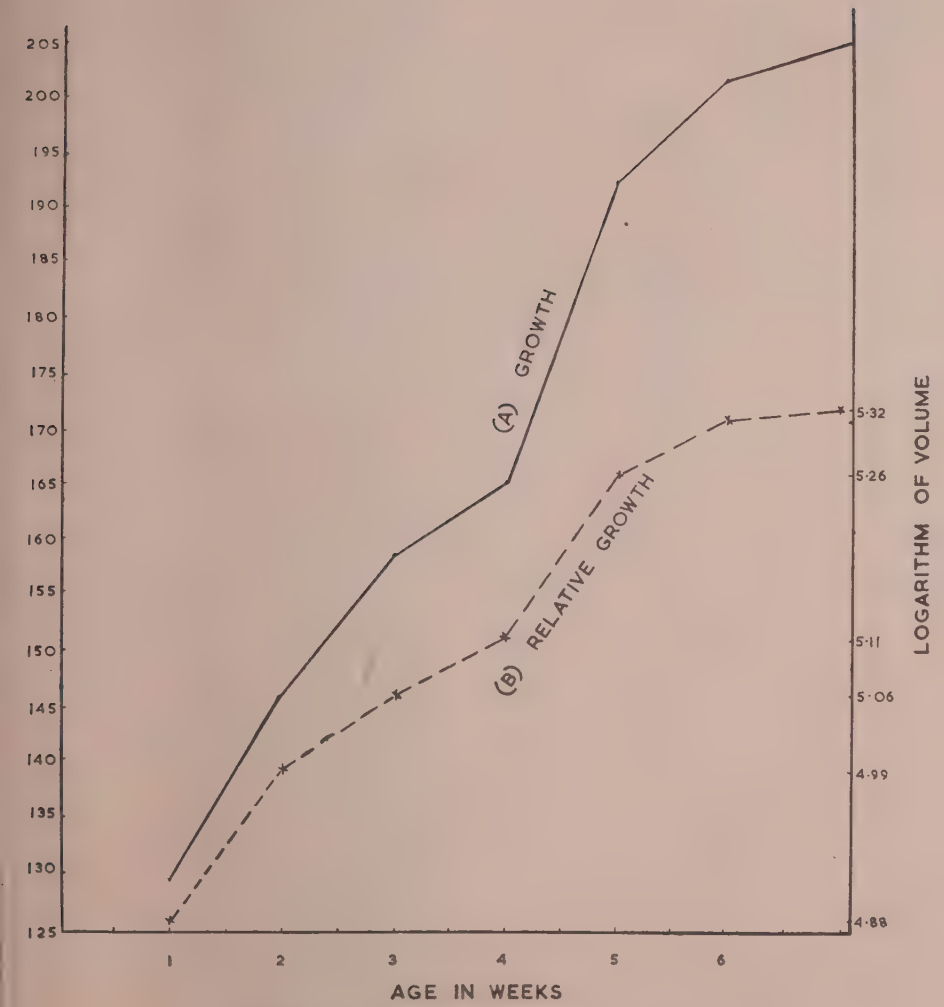

FIG. 7. Growth curves for the *Monthan* variety in respect of volume

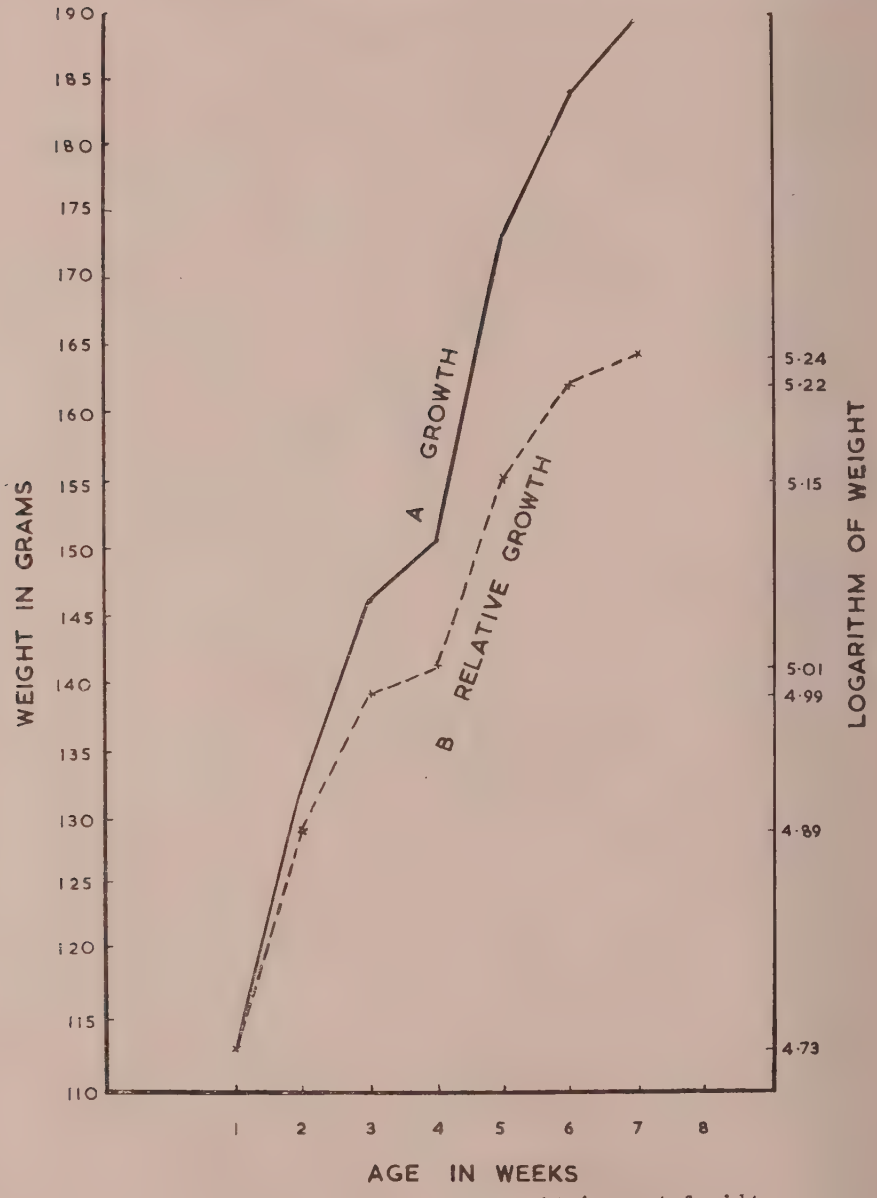

Fig. 8. Growth curves for the *Monthan* variety in respect of weight

TABLE 11-*a*

Weekly length measurements of the Monthan *variety*

Age of the developing fruit in weeks	*Length in mm.	Rate of increment in mm. per week	Napierian logarithm of length	Relative increment per cent of length per week
1	89·4		4·4981	
2	111·3	21·9	4·7122	21·91
3	124·6	13·3	4·8251	11·29
4	130·3	5·7	4·8698	4·47
5	143·7	13·4	4·9677	9·79
6	152·2	8·5	5·0252	3·75
7	160·9	8·7	5·0807	5·55
8	165·6	4·7	5·1096	2·89
9	170·8	5·2	5·1404	3·08
10	175·9	5·1	5·1699	2·95
11	179·5	3·6	5·1903	2·04
12	182·2	2·7	5·2051	1·48
13	183·8	1·6	5·2138	0·87
14	185·3	1·5	5·2220	0·82
15	187·4	2·1	5·2333	1·13
16	188·9	1·5	5·2414	0·81

*Mean of 36 measurements.

TABLE II-*b*

Weekly measurements of circumference (girth) in fruit development studies on Monthan-*variety*

Age of the developing fruit in weeks	*Girth in mm.	Rate of increment in mm. per week	Napierian logarithm or girth	Relative increment per cent of girth per week
1	64·2		4·1620	
		28·2		36·41
2	92·4		4·5261	
		15·1		15·16
3	107·5		4·6777	
		6·9		6·20
4	114·4		4·7397	
		5·0		4·30
5	119·4		4·7827	
		2·9		2·38
6	122·3		4·8065	
		3·6		2·90
7	125·9		4·8355	
		5·3		4·12
8	131·2		4·8767	
		6·5		4·85
9	137·7		4·9252	
		5·2		3·69
10	142·9		4·9621	
		4·6		3·19
11	147·5		4·9940	
		3·4		2·25
12	150·9		5·0165	
		2·6		1·72
13	153·5		5·0337	
		2·4		1·56
14	155·9		5·0493	
		4·0		2·54
15	159·9		5·0747	
		0·9		0·53
16	160·8		5·0800	

*Mean of 36 measurements.

TABLE II-*c*

Weekly measurements of weight in fruit development studies on Monthan *variety*

Age of the developing fruit in weeks	*Weight in grams	Rate of increment in grams per week	Napierian logarithm of weight	Relative increment percent of weight per week
10	112·8		4·7255	
		19·5		15·95
11	132·8		4·8850	
		13·9		10·00
12	146·2		4·9850	
		4·2		2·83
13	150·4		5·0133	
		22·5		13·93
14	172·9		5·1526	
		11·5		6·46
15	184·4		5·2172	
		5·0		2·68
16	189·4		5·2440	

*Mean of 18 measurements.

TABLE II-*d*

Weekly measurement of volume in fruit development studies on Monthan *variety*

Age of the developing fruit in weeks	*Volume in cc.	Rate of increment in cc. per week	Napierian logarithm of volume	Relative increment percent of volume per week
10	129·5		4·8638	
		16·7		12·12
11	146·2		4·9850	
		11·9		7·82
12	158·1		5·0682	
		7·2		4·46
13	165·3		5·1078	
		27·3		15·28
14	192·6		5·2606	
		9·1		4·16
15	201·7		5·3067	
		23·2		1·58
16	204.9		5·3225	

*Mean of 18 measurements.

Fig. 9. *Poovan* banana

but the details of which are not considered as strictly relevent to the data under discussion.

Simmonds [1953] has shown that the growth curves of prathenocarpic banana fruits by contrast with seeded diploids are much variable. Seeded types are characteristic in having sigmoid volume curves. It has also been shown that edible clones derived from *Musa acuminata* have predominantly concave growth curves while those from *Musa balbisiana* have convex and those from the hybrids have intermediate growth curves.

In the case of the *Poovan* variety which has affinity towards *Musa acuminata* the volume curve is slightly concave or roughly straight and there is an early growth check in respect of length, weight and volume (Fig. 1-*a*, 2, 3 and 4).

In the case of the *Monthan* variety which shows more affinity towards *Musa balbisiana*, the growth curve is convex with no early growth check in respect of length, circumference, weight and volume (Figs. 5, 6, 7 and 8). Simmonds [1953] has concluded that a particular type of fruit development is characteristic of a close and that there is a close connection with their specific origins.

Summary

Measurements of fruit development of the two banana varieties *Poovan* and *Monthan* were recorded at weekly intervals during the period August to December 1953. Growth curves in respect of length, girth, volume and weight were constructed.

This investigation has thrown light on the optimum stage of harvest of the bunches of the varieties *Poovan* and *Monthan* and has also indicated their possible affinities to the respective wild species namely *Musa acuminata* and *Musa balbisiana*.

Acknowledgement

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ABNORMALITIES IN BANANAS—III

By T. Gopalan Nayar, V. S. Seshadri and C. M. Bakthavathsalu

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THE production of multiple inflorescences in bananas have been recorded by Kander [1923], Davis [1946] and by Nayar and others [1951, 1954]. Kander has recorded an abnormal case in which a three-month old banana plant had thrown out a bunch. Davis has given particulars of a plant with five bunches. The authors, recently, spotted a *Rasthali* plant in which the abnormal emergence of two bunches from the base of the pseudostem in addition to the normal bunch was observed.

Abnormal production of banana bunches from the base of the pseudostem was as following :

(1) normal bunch on the top ;

(2) two abnormal bunches from the base.

The particular *Rasthali* plant (Syn. Mutheli, Martaman, Rasa Bale, Silk Fig.) was located in a private garden in Srirangam, Tiruchirapalli district. Except for the smaller size of the plant there were no variations in the morphological characters. The height of the plant was 128 cm. with a girth of only 25 cm. at base.

Following are the details of the normal and the two abnormal bunches of the plant :

Normal bunch. There were only two hands, the first hand containing only four fruits and the second only six. The fruits were under sized and the average length of the fruits was 9·1 cm. and girth 8·6 cm.

Abnormal bunch (1). This was a very tiny bunch, with only one hand containing two fingers. The average length of the fruit was 4·5 cm. and girth 4·2 cm. There were five scars indicating the dehiscence of the female flowers.

Abnormal bunch (2). This bunch also has emerged from the base of the pseudostem. Only one hand with one finger has developed in the bunch, the finger length and girth being 4·3 and 4·5 cm. respectively. There were four scars indicating that the other female flowers produced have shed.

Further examination of the base of the pseudostem, to locate the place of origin of the bunches, has shown that the peduncles of both the bunches have branched from the main axis at the base. An instance of forking or branching of two inflorescences on the top which developed two good *Poovan* bunches has already been recorded by Nair *et al.* [1954].

Premature emergence of inflorescence

Another abnormality noticed was the flowering of a *Nendran* sucker which measured a height of only 25 cm. This abnormality was recorded from a private garden near Karur, Tiruchirapally district. This plant was the fourth follower of the clump. It was much undersized and was lacking very much in vigour. All the female flowers in the inflorescence have dropped and at the time of examination only male flowers were present. These also were much below normal size. The throwing out of an inflorescence by a *Nendran* plant, which is just one foot tall, has not been observed so far. Such a phenomenon reveals the range of variation in plant size and also the unusual occurrence of the fruiting phase even in such a tiny specimen of a plant; an occurrence the repetition of which is to be avoided and which is probably due to the degeneration of the rhizome as a result of unsuitable environmental and soil conditions. Such features are at times met with in banana variety *Mauritius* which is not normally ratooned. It may be mentioned in this connection that the variety *Nendran* is also very rarely ratooned. The limitation of taking too many ratoon crops especially under unfavourable conditions at least with reference to certain varieties like *Nendran* is indicated.

Reversion of fruit characters

The variety *Motta Poovan*, as it is called, is characterised by the absence of apex in the fruits and in all other respects it resembles *Poovan* (Syn. Lal Velchi, Champa, etc.), the leading commercial variety of Madras. At the Central Banana Research Station, Aduthurai in one bunch of this variety, it was observed that the fruits in the first few hands showed distinct apex, while the rest were without apex.

The observations recorded are as under :

Number of hands with distinct apex like ordinary *Poovan*	5
Number of hands with characteristic absence of apex like *Motta Poovan*	4
Number of fruits with distinct apex like ordinary *Poovan*	75
Number of fruits with the characteristic absence of apex like *Motta Poovan*	49

Fruit size and characters were similar to *Poovan*.

This is a distinct case of reversion of the sport *Motta Poovan* to the variety *Poovan*. Jacob [1951] has reported that he has not noted such reversion and such a reversion has now been noted for the first time.

ACKNOWLEDGEMENT

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ALGAL FOOD OF SOME LOCAL FISHES

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In connection with a programme of fertilization experiments on fisheries ponds, for increasing production, it was thought advisable to examine the gut-contents of fingerlings of commonly occurring fishes at Banaras. A number of investigations of this nature have been conducted in India, but they relate either to marine and estuarine fishes [Mookerjee, Ganguly and Sircar, 1946 ; Pillay, 1946] or to fresh water fishes confined to a limited part of the country, viz., Bengal and Madras [Mookerjee, 1944, 1945 ; Bhattacharya, 1946 ; Mookerjee and Basu, 1946 ; Mookerjee, Ganguly and Islam, 1946 ; Mookerjee, Ganguly and Pakrasi, 1947 ; Mookerjee and Gupta, 1946 ; Spurgeon, 1948 ; Chacko and Jole, 1948*a*, 1948*b*, Alikunhi and Rao, 1948*a*, 1948*b*]. These investigations confirm the prevalent view that algae form a substantial part of the food of fish-fries. In certain quarters, however, opinion has also been expressed, [as quoted by Tilden, 1929] that the algae may be taken in accidentally along with the current of water through the bronchial chamber of fishes. In order to certify this position, a few culture experiments were also conducted with Rohu (*Labeo rohita*) fingerlings collected from a tank at Banaras.

Method

A large number of fingerlings of six different species of fishes were collected from a temporary pond (Sakaldiha, Banaras) towards the close of December, 1948. The fingerlings were fixed on the spot in 5 per cent formalin. In the laboratory, each fish was carefully dissected and its alimentary canal taken out and preserved in 5 per cent formalin. The entire gut-content was examined from one end of the alimentary canal to the other under the microscope. Specific identification of the algae encountered was attempted as far as possible. A systematic list of the algae present together with the percentage composition of other items, is recorded in Table I.

From the above data it is clear that *Chela* sp., *Puntius sophore* and *Esomus danricus* possessed a large number of algae in their gut, *Ophicephalus punctatus* and *Mystus bleekeri* a few while *Ambassis ranga* and *A. baculis* very few or none at all.

* The work was completed in the Department of Botany, Banaras Hindu University where the author held a Research Fellowship during 1948-50 of the U. P. Scientific Research Grants Committee.

TABLE I

Systematic list of algae

Algae	*Chela* sp.	*Ophicephalus punctatus* Bloch.	*Mystus bleekeri* (Day)	*Puntius sophore* Ham.	*Esomus danricus* (Ham.)	*Ambassis ranga* (Ham *A. baculis* (Ham.)
Length	1·8 in.-2·4 in.	2 in.-2·5 in.	1·5 in.-2 in.	1 in.	1 in.	1·3 in.-1·5 in
Percentage of Algae	15—20 per cent	5—10 per cent	5—10 per cent	15—20 per cent	20 per cent	5 per cent
Pandorina morum (Müll.) Bory	xxxx	—	x	—	x	—
Pleodorina sp.	x	—	—	—	—	—
Characium apiculatum Rabenh.	xx	x	—	x	—	—
Tetraedron trigonum (Naegeli) Hans.	—	—	—	—	x	—
Actinastrum gracillimum Smith	xxx	—	—	—	—	—
Ankistrodesmus falcatus (Corda.) Ralfs.	x	xx	x	xx	xxxx	—
Pediastrum duplex Meyen	x	—	—	xx	—	—
P. pertusum Kütz.	x	—	xx	—	xxxx	—
P. angulosum Ehr.	—	—	—	—	xx	—
Coelastrum sphaericum Naeg.	—	—	—	—	xxx	—
Scenedesmus quadricauda (Turp.) Bréb.	x	x	xx	x	xxxxx	—
S. acuminatus (Lagerh.) Chod.	x	—	—	x	—	—
S. bijuja (Turp.) Lagerh.	—	—	—	—	x	—
Ulothrix oscillarina Kütz.	xxx	—	xx	xx	x	—
U. tenuissima Kütz.	x	xx	x	—	x	—
Chaetophora elegans (Roth) Ag.	—	—	xx	—	—	—
Stigeoclonium amoenum Kütz.	xxx	x	x	xx	x	—
S. farctum Berth.	x	—	x	xx	—	—
Phycopeltis epiphyton Müll.	—	x	—	—	—	—
Oedogonium spp.	xxxxx	xxxx	xxxx	xxxxx	xx	—
Bulbochaete sp.	xxx	—	—	—	—	—
Spirogyra sp.	xxxx	xx	xx	—	x	—
Mougeotia sp.	x	—	—	—	—	—
Closterium moniliferum Bory.	xxx	xx	xxx	xxxx	xxx	—
C. leibleinii Kütz.	x	—	—	—	xx	—
C. acrosum Schrank	—	—	—	xxxx	xx	—
C. obtusatum Schimidle	xxx	xx	xxx	xxxxx	xx	—
C. cucumis Corda.	xx	—	—	—	—	
C. obliqum Nordat.	xx	—	x	—	xx	—
C. garroiense Ry. & Biss	xx	—	x	—	xx	—
C. granatum Bréb.	x	—	—	x	xx	—
Pleurotaenium sp.	x	—	—	—	—	—

TABLE I—*contd.*

Systematic list of algae—contd.

Algae	*Chela* sp.	*Ophicephalus punctatus* Bloch.	*Mystus bleekeri* (Day)	*Puntius sophore* Ham.	*Esomus danricus* (Ham.)	*Ambassis ranga* (Ham.) *A. baculis* (Ham.)
Fragilaria intermedia Grun.	xx	x	xx	x	—	—
Synedra ulna (Nitz.) Ehr.	xxxx	xxx	xxxx	xxxx	xx	—
Achanthes hungarica Grun.	xxx	—	—	x	—	—
Cocconeis placentula Ehr.	xx	x	xxx	—	—	—
Amphora ovalis Kütz.	xxx	—	—	—	—	—
Cymbella Ehrenbergii Kütz.	x	xx	xx	xx	xx	—
Gomphonema subapicatum Fritsch & Rich.	xxxx	xxx	xxxx	xxxxx	xxxx	xxx
G. abbreviatum (Ag.) Kütz.	xxx	xx	xxxx	xxx	xxx	x
Navicula halophila (Grun.) Clev.	x	x	x	—	x	—
Pinnularia acrosphaera Bréb.	xxxx	xxx	xxxx	xxx	x	xxx
Euglena spirogyra Ehr.	xx	—	—	xx	xx	—
E. acus Ehr.	—	—	xxx	xxxxx	xxxxx	x
Phacus curvicauda Swir.	x	—	xx	xxxxx	xx	—
P. haemelii Lieg.	—	—	—	xx	—	x
Trachelomonas sp.	x	—	—	x	xx	—
Dactylococcopsis irregularis Smith.	xx	—	—	—	—	—
Raphidiopsis indica Singh	x	—	—	—	—	—
Microchaete uberrima minor Carter	x	—	—	—	—	—
Cylindrospermum sp.	x	—	—	—	—	—
Nostoc spongiaeformae Ag.	xxx	—	—	—	—	—
Spirulina tenuis (Brühl et Biswas) Geitler.	—	—	—	x	—	—
Oscillatoria annae Van Gowr.	x	—	xx	xxx	—	—
O. obscura Brühl et Biswas	xxxx	xx	x	xxxxx	xx	x
Phormidium frigidum Fritsch	—	—	—	—	—	x
Lyngbya lutea (Ag.) Gom.	—	xx	xxx	x	—	—
Moss protomema	5 per cent	—	—	—	2 per cent	—
Oospores, Zygospores and fungus spores.	5 per cent	3 per cent	2 per cent	—	3 per cent	—
Decaying leaves and others	10 per cent	—	3 per cent	—	—	—
Crustaceans and insects	50—60 per cent	87—92 per cent	77—85 per cent	—	—	95 per cent
Mud	5—10 per cent	5 per cent	5—10 per cent	5—10 per cent	75 per cent	—

— denotes absence of the organism in the gut,
x denotes presence, rare,
xx denotes presence, occasional,
xxx denotes presence, common,
xxxx denotes presence, very common,
xxxx* denotes presence, abundant.

Fingerlings of Rohu (*Labeo rohita*) fish were collected from Jagatganj tank, Banaras, on the 30th January, 1949. Five big earthen tubs were fixed in ground of the Botanical Garden, Banaras Hindu University. Each tub was cleaned thoroughly so as to make sure that no source of organic matter was present. The tubs were filled with pond water which, at the time of collection, was free from planktonic algae to a large extent. Two of the tubs were inoculated with a bloom of *Microcystis aeruginosa* Kütz., another two with a bloom of Euglenineae and the fifth with a bloom of *Chlamydomonas* sp., all collected on the same day from Ramkatora, Durgakund and a tank near Engineering College of the University, respectively. In each tub a number of the collected fingerlings were set free and a few were kept in a reservoir without algae as control. Some fingerlings were, however, examined for their gut-contents, at the time of inoculation. Later on a few fingerlings from each tub were examined for their gut contents each day. The experiment lasted for six days when most of the fingerlings had been examined. The fishes in the control continued to live.

The results of the microscopic examination of the gut contents of fingerlings from the above three sets of tubs, as well as of the fingerlings at the time of inoculation are given in Table II.

TABLE II

Results of microscopic examination of the gut contents of fingerlings

Algae present in the gut of fingerlings prior to inoculation	Algae present in the gut of fingerlings from *Microcystis* tub	Algae present in the gut of fingerlings from Euglenineae tub	Algae present in the gut of fingerlings from *Chlamydomonas* tub
Ankistrodesmus falcatus	*Microcystis aeruginosa*	*Scenedesmus quadricauda*	*Dactylococcopsis irregularis*
Scenedesmus quadricauda	*Synedra ulna*	*Euglena spirogyra* (very common)	*Phacus curvicauda*
S. acuminatus	*Gomphonema subapicatum*	*Phacus curvicauda*	*Chlamydomonas* sp (Common)
Synedra ulna		*Gomphonema subapicatum*	*Raphidiopsis indica*
Cymbella ehrenbergii		(empty frustules)	
Gomphonema subapicatum		*Dactylococcopsis irregularis*	
Pinnularia acrosphaera			
Phacus curvicauda			
Trachelomonas sp.			
Dactylococcopsis irregularis			
Oscillatoria obscura			
Zygotes and Zygospore of various algae			
Teleutospore of *Puccinia graminis*			

It can be observed from Table II that when the fingerlings were kept on a particular diet of organic matter commonly found in natural waters locally, in the three

tubs, in the form of three different kinds of algal bloom, the analysis of the gut contents showed those algae in enormous quantities. Further, various stages of disintegration of the algae were observed. One of the most interesting facts which was noted was that the fingerlings took *Microcystis aeruginosa*, *Euglena* and *Chlamydomonas* in a decreasing order. This may indicate that there is a certain degree of selectivity of algal food on the part of the fingerlings.

It was also observed that the lower portion of the intestine of fingerlings contained mostly chitinous remains and appendages of various crustaceans and insects and mud in the case of mud eaters. In a few cases, however, diatoms were present even in a healthy condition in the lower portion of the intestine, but in the majority of cases the contents of the diatom frustules were either absent or frustules were broken and the contents missing.

The results presented here, therefore, support the prevalent view that algae are utilized as food by fingerlings of fishes. Further, it can be seen that all fishes do not take algae in the same proportion.

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A SURVEY OF AGRONOMIC RESEARCH PROGRAMMES IN INDIA

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(With 1 Text-Figure)

A QUANTITATIVE assessment of the progress of agricultural research in the country indicates the manner and the extent to which the resources of the country in respect of research workers, funds and other facilities are being utilised for the solution of the most important problems facing the country and provides useful information on the efficiency of methods adopted in investigating these problems. Further, the various States in the country benefit considerably by sharing precise information on current agronomic experiments in the other States. With this object in view, the Indian Council of Agricultural Research conducted in 1953 a survey of the agronomic research programmes that were in progress during the year 1952-53 in various States of the Indian Union.

Scope and Conduct of the Survey

The survey was intended to cover all agricultural crops. For annual crops, it included experiments sown or planted between April 1, 1952 and March 31, 1953 and for fruits, nuts and other perennial crops, every experiment on which a harvest was recorded within this period. A questionnaire containing all items on which information is to be collected, was sent through the Directors of Agriculture of different States and Directors of Central Research Institutes to the various agronomic research stations. A copy of the questionnaire is given in Appendix I. The information required to be furnished included (i) purpose of the experiment, (ii) whether the experiment was conducted under an I.C.A.R. scheme or a Commodity Committee scheme or the State itself and (iii) the basal manure used, if any, given to all plots in addition to the treatments. Under 'Experimental treatments' were to be mentioned treatments under investigation with full description. If the treatments were manurial, the methods of application and chemical composition (especially of organic manures) would be stated. If different agronomic practices, e.g., irrigation schedules or spacing of plants were under test, these would be described fully and quantitatively. Under 'design' a very brief description would be given about the layout of the experiment, e.g., '6 randomised blocks each of 5 plots' and so on.

The experimental stations were supplied with printed instructions for filling the forms (Appendix II). The information was restricted to field experiments wholly or partially concerned with questions of agronomic practices, rates, types and methods of fertilizer application, methods of cultivation, seed-rates and spacing,

irrigation schedules, mixed crops, rotation of crops and so on. Experiments concerning solely with the comparison of varieties, with plant protection and with grazing and animal nutrition were excluded, as also trials under the 'crop weather scheme'. Varietal trials in which fertilizers or other agronomic factors were tested simultaneously were, however, included.

In order to distinguish the experiments on cultivators' fields from those at research stations the letters "C.F." were asked to be entered against 'location' and followed by a list of the districts in the State in which these experiments were laid out. Experiments on cultivators' fields have been summarized separately, because of their different objectives and designs from those at the research stations.

Extent of Response

The States were requested to furnish the information by the end of May, 1953. Even though most of the States sent in the information before this date, the information was flowing in till the end of the year 1953. All the States except Rajasthan, Himachal Pradesh and Jammu and Kashmir provided the required information. The total number of experiments regarding which information has been received is 3980 out of which 1533 experiments were conducted at research stations while the remaining 2447 were laid out on cultivators' fields.

Summarisation of the data has been attempted both in its qualitative and quantitative aspects. The former covers the classification of experiments as manurial, cultural, etc. replicated or not, type of treatments studied, source of finance and the amount of experimentation done on each crop whereas the latter deals with the quantitative assessment of the relative amount of information provided by these experiments on different treatments under investigation by the application of a scoring technique which was developed for this purpose.

Experiments at Research Stations

Summarization of the data

Spread of experiments among States. The data for experiments at research stations were summarized by preparing tables showing the distribution of experiments according to various classifications.

Table I gives Statewise distribution of the experiments according to sponsoring authority, Commodity Committees, or the Indian Council of Agricultural Research or the States themselves. The table shows that 29 per cent of the total number of experiments were conducted under the schemes sponsored by either Indian Council of Agricultural Research or Commodity Committees. It is also seen from the Table

TABLE I

Distribution and classification of experiments conducted at research stations

State/Central Institute	Number of experiments sponsored by			Total No. of experiments reported	Per cent number of experiments reported
	I.C.A.R.	Commodity Committees	State		
States—					
Bombay	6	37	253	296	19·3
Uttar Pradesh	..	25	194	219	14·3
Punjab	41	60	91	192	12·5
Madras	7	32	138	177	11·6
Bihar	..	113	57	170	11·1
Madhya Pradesh	3	..	106	109	7·1
West Bengal	26	5	18	49	3·2
Hyderabad	4	..	32	36	2·3
Mysore	2	3	25	30	2·0
Madhya Bharat	..	..	20	20	1·3
Orissa	10	2	5	17	1·1
Assam	..	5	11	16	1·0
Pepsu	..	8	5	13	0·8
Ajmer	..	..	10	10	0·7
Travancore-Cochin	1	5	4	10	0·7
Bhopal	..	..	6	6	0·4
Coorg	1	..	1	2	0·1
Vindhya Pradesh	..	..	2	2	0·1
Saurashtra	..	..	1	1	0·1
Central Institutes—					
Indian Agricultural Research Institute (I.A.R.I.)	..	4	75	79	..
Central Potato Research Institute (C.P.R.I.)	..	..	23	23	..
Central Tobacco Research Institute (C.R.R.I.)	..	22	..	22	10·3
Central Jute Research Station (C.J.R.S.)	..	19	..	19	..
Cenral Rice Research Institute (C.R.R.I.)	..	..	13	13	..
Central Coconut Research Station (C.C.R.S.)	..	2	..	2	..
Total	101	342	1,090	1,533	100·00

that about 19 per cent of the total number of experiments reported were conducted in Bombay and the next largest contribution of 14 per cent came from Uttar Pradesh. Punjab reported 13 per cent of the total number of experiments while Madras and Bihar have conducted 12 per cent and 11 per cent respectively. These five States and Madhya Pradesh collectively reported 76 per cent of the agronomic experiments conducted in the country in 1952-53 while the remaining thirteen states accounted for only 14 per cent of the total number of experiments reported. The number of experiments at the Central Research Institutes formed 10 per cent of the total number of experiments.

To obtain an idea of the manner of distribution of the resources for experimentation on different crops, Table II has been prepared to give Statewise distribution fo the experiments according to different crops. For this purpose as well as for further study all the 130 experiments reported under mixed crops and rotations have been excluded, as their objectives are different from those conducted on individual crops. It is seen that the majority of the experiments constituting 51 per cent were those on cereals such as paddy and wheat. Table II also indicates that considerable attention was paid to sugarcane and cotton, 23 per cent of the experiments being devoted to these crops together. It can be seen that, as expected, more attention is being paid to cash crops like cotton and sugarcane than to food crops ; while the area under food crops is nearly 72 per cent and that under cotton and sugarcane together is 6 per cent, the proportion of experiments on these two groups of crops is 54 per cent and 23 per cent respectively. Further, more attention is devoted to wheat than to *jowar* and *bajra* even though the area under the latter two crops is considerably greater than that on wheat. Between sugarcane and cotton more experimentation is being done on sugarcane although the area under cotton is three times that under sugarcane. Potatoes received more attention considering the area under this crop. Similar divergence between the importance of a crop as measured by its area and the amount of experimentation devoted to it are to be found in individual States.

This question has been further examined with reference to certain important crops in Table III, where, in addition to the number of experiments reported on a crop, the area under a crop in a State is expressed both as a percentage of the total cropped area in the State and also as a percentage of the area under that crop in the Union. Table III reveals, for example, that in Bombay only 18 per cent of the total number of experiments were devoted to *jowar* when compared to 21 per cent on paddy even though the area under *jowar* in the State is nearly four times that under paddy. Further, between sugarcane and cotton, only 6 per cent of the total number of experiments in the States were devoted to cotton while sugarcane had 11 per cent even though the area under cotton is 16 times that of sugarcane. In Madras too, greater attention was paid to sugarcane than to cotton while the area under cotton was considerably greater than that under sugarcane. In Uttar Pradesh, while the area under wheat and paddy is more or less the same, the number of experiments conducted on paddy is 28 per cent of the total as compared to 45 per cent

TABLE II

Cropwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras	Bihar	Madhya Pradesh	West Bengal
Crop—							
Paddy	57	50	11	67	13	26	19
Wheat	31	80	48	..	4	25	..
Jowar	48	9	1	5	..	15	..
Maize	..	5	6	..	12	..	1
Bajra	10	..	..	..	..	..	..
Other cereals	4	5	4	9	..	..	..
Pulses	7	1	24	..	4	3	1
Oilseeds	22	1	11	5	5	4	4
Potatoes	..	9	..	6	2	..	6
Sugarcane	30	14	20	24	121	..	1
Cotton	17	4	17	14	..	20	..
Vegetables	7	..	3	5	6	..	2
Spices	6	..	..	5	..	..	..
Tubers (other than potatoes)	1	..	4	..	..	1	..
Fruits	9	..	6	12	2	..	15
Tobacco	4	..	11	..	..	..	..
Tea	..	..	3	..	..	..	..
Coconuts	..	..	..	8	..	..	..
Jute	..	..	..	..	..	..	..
Fodder	15	..	10	..	1	1	..
Total	268	178	179	160	170	95	49

TABLE II—*contd.*

Cropwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	Hydera-bad	Mysore	Madhya Bharat	Orissa	Assam	Pepsu	Ajmer
Crop—							
Paddy	14	18	1	5	9	..	..
Wheat	3	..	5	..	..	2	10
Jowar	3	..	2	..	..	..	..
Maize	3	..	..	..	..	1	..
Bajra	..	..	..	..	..	..	..
Other cereals	..	..	..	..	..	..	..
Pulses	..	..	..	..	..	..	..
Oilseeds	..	..	1	..	5	1	..
Potatoes	..	..	..	..	..	1	..
Sugarcane	..	2	..	2	2	..	..
Cotton	9	8	8	..	..	8	..
Vegetables	..	..	..	1	..	..	..
Spices	..	..	..	4	..	..	..
Tubers (other than potatoes)	..	2	..	2	..	..	..
Fruits	..	..	..	2	..	..	..
Tobacco	..	..	..	..	..	..	..
Tea	..	..	..	..	..	..	..
Coconuts	..	..	..	..	..	..	..
Jute	..	..	..	..	..	..	..
Fodder	..	..	..	..	..	..	..
Total	32	30	17	16	16	13	10

TABLE II—*contd.*

Cropwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	Travancore-Cochin	Bhopal	Coorg	Vindhya Pradesh	Saurashtra	I.A.R.I.	C.P.R.I.
Crop—							
Paddy	5	..	1	1	..	5	..
Wheat	..	6	..	1	1	20	..
Jowar	..	..	..	..	..	1	..
Maize	..	..	..	..	..	11	..
Bajra	..	..	..	..	..	1	..
Other Cereals	..	..	..	..	..	4	..
Pulses	..	..	..	..	..	1	..
Oil seeds	..	..	..	..	..	2	..
Potatoes	..	..	..	..	..	3	23
Sugarcane	..	..	..	..	..	4	..
Cotton	..	..	..	..	..	3	..
Vegetables	..	..	..	..	..	3	..
Spices	..	..	..	..	..	..	..
Tubers (other than potatoes)	..	..	..	..	..	1	..
Fruits	..	..	..	..	..	..	..
Tobacco	..	..	..	..	..	2	..
Tea	..	..	..	..	..	..	..
Coconuts	5	..	..	..	..	..	..
Jute	..	..	..	..	..	1	..
Fodder	..	..	1	..	..	8	..
Total	10	6	2	2	1	70	23

TABLE II—*contd.*

Cropwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	C.T.R.I.	C.J.R.S.	C.R.R.I.	C.C.R.S.	Total	Per cent number of experiments	Per cent acreage under the crop in the Union
Crop—							
Paddy	..	..	13	..	315	22·4	22·9
Wheat	..	..	..	..	236	16·8	7·3
Jowar	..	..	..	..	84	6·0	12 2
Maize	..	..	..	..	39	2·8	2·6
Bajra	..	..	..	..	11	0·8	7·0
Other Cereals	..	..	..	..	26	1·8	4·4
Pulses	..	..	..	..	41	2·9	16·0
Oil seeds	..	..	..	..	61	4·3	7·9
Potatoes	..	..	..	..	50	3·6	0·1
Sugarcane	..	..	..	..	220	15·7	1·4
Cotton	..	..	..	..	108	7·7	4·2
Vegetables	..	..	..	..	27	1·9	..
Spices	..	..	..	..	15	1·1	1·0
Tubers (other than potatoes)	..	..	..	..	11	0·8	0·1
Fruits	..	..	..	..	46	3·3	..
Tobacco	22	..	..	..	39	2·8	0·2
Tea	..	..	..	..	3	0·2	0·2
Coconuts	..	..	..	2	15	1·1	0·5
Jute	..	19	..	..	20	1·4	0·4
Fodder	..	..	..	..	36	2·6	..
Total	22	19	13	2	1403	100·00	88·4

TABLE III

Statewise distribution of experiments for crops and corresponding per cent area under each crop

State		Bombay	Uttar Pradesh	Punjab	Madras	Bihar	Madhya Pradesh
Crop							
Paddy	(a)	57	50	11	67	13	26
	(b)	7	18	3	29	47	28
	(c)	4	12	0·7	14	17	12
Wheat	(a)	31	80	48	—	4	25
	(b)	5	17	21	—	5	7
	(c)	9	36	13	—	6	11
Jowar	(a)	48	9	1	5	—	15
	(b)	28	5	4	13	0·1	15
	(c)	30	6	1	12	—	13
Maize	(a)	—	5	6	—	12	—
	(b)	1	4	6	0·1	6	0·9
	(c)	5	26	10	0·6	21	4
Bajra	(a)	10	—	—	—	—	—
	(b)	15	5	14	7	0·1	0·3
	(c)	27	12	9	10	0·1	0·5
Potatoes	(a)	—	9	—	6	2	—
	(b)	—	0·4	—	—	0·4	—
	(c)	5	48	3	4	23	2
Sugarcane	(a)	30	14	20	24	121	—
	(b)	0·5	5	2	0·6	1	0·2
	(c)	5	59	8	5	9	1
Cotton	(a)	17	4	17	14	—	20
	(b)	7	0·3	3	4	—	10
	(c)	22	1	3	10	0·1	24
Total number of experiments reported		268	178	179	160	170	95

— in the case of number of experiments indicates absence.
— in the case of area under a crop indicates less than 0·1.
Blank space indicates either the corresponding figures are not available or the crop is not grown.
(a) No. of experiments conducted on the crop.
(b) Per cent area under the crop to the total cropped area in the State.
(c) Per cent area under the crop in the State to the total area under the crop in the Union.

TABLE III—*contd.*

Statewise distribution of experiments for crops and corresponding per cent area under each crop

State		West Bengal	Hyderabad	Mysore	Madhya Bharat	Orissa
Crop						
Paddy	(*a*)	19	14	18	1	5
	(*b*)	74	5	10	2	66
	(*c*)	14	2	1	0·3	12
Wheat	(*a*)	—	3	—	5	—
	(*b*)	0·8	1	—	15	—
	(*c*)	0·5	2	—	7	—
Jowar	(*a*)	—	3	—	2	—
	(*b*)	—	29	11	27	0·4
	(*c*)	—	19	2	8	0·1
Maize	(*a*)	1	3	—	—	—
	(*b*)	0·7	1	—	4	0·4
	(*c*)	1	5	—	6	0·7
Bajra	(*a*)	—	—	—	—	—
	(*b*)	—	4	2	4	0·1
	(*c*)	—	5	0·8	2	—
Potatoes	(*a*)	6	—	—	—	—
	(*b*)		—	—	—	0·2
	(*c*)		0·2	2	1	5
Sugarcane	(*a*)	1	—	2	—	2
	(*b*)	0·4	0·4	0·7	0·4	0·5
	(*c*)	1	2	1	1	1
Cotton	(*a*)	—	9	8	8	—
	(*b*)	—	10	4	12	0·2
	(*c*)	—	19	3	10	0·2
Total number of experiments reported		49	32	30	17	16

— in the case of number of experiments indicates absence.
— in the case of area under a crop indicates less than 0·1.
Blank space indicates either the corresponding figures are not available or the crop is not grown.
(*a*) No. of experiments conducted on the crop.
(*b*) Per cent area under the crop to the total cropped area in the State.
(*c*) Per cent area under the crop in the State to the total area under the crop in the Union.

TABLE III—*contd.*

Statewise distribution of experiments for crops and corresponding per cent area under each crop

State		Assam	Pepsu	Ajmer	Travancore-Cochin	Bhopal
Crop						
Paddy	(*a*)	9	—	—	5	—
	(*b*)	64	0·8	—	36	2
	(*c*)	6	—	—	2	—
Wheat	(*a*)	—	2	7	—	6
	(*b*)	—	17	7	—	26
	(*c*)	—	7	0·1	—	2
Jowar	(*a*)	—	—	—	—	—
	(*b*)		2	25	—	12
	(*c*)		0·3	0·3	—	0·5
Maize	(*a*)	—	1	—	—	—
	(*b*)	0·6	4	17	0·2	1
	(*c*)	0·5	2	0·9	—	0·2
Bajra	(*a*)	—	—	—	—	—
	(*b*)		15	9	—	—
	(*c*)		3	0·2	—	—
Potatoes	(*a*)	—	1	—	—	—
	(*b*)		—		—	—
	(*c*)		0·7		0·2	—
Sugarcane	(*a*)	2	—	—	—	—
	(*b*)	0·9	1	0·2	0·5	0·6
	(*c*)	1	2	—	0·4	0·2
Cotton	(*a*)	—	8		—	—
	(*b*)	0·5	5	4	0·5	3
	(*c*)	0·2	2	0·1	0·1	0·4
Total number of experiments reported		16	13	10	10	6

— in the case of number of experiments indicates absence.
— in the case of area under a crop indicates less than 0·1.
Blank space indicates either the corresponding figures are not available or the crop is not grown.
(*a*) No. of experiments conducted on the crop.
(*b*) Per cent area under the crop to the total cropped area in the State.
(*c*) Per cent area under the crop in the State to the total area under the crop in the Union.

TABLE III—*concld.*

Statewise distribution of experiments for crops and corresponding per cent area under each crop

State		Coorg	Vindhya Pradesh	Saurashtra	Number of experiments reported under the crop	Per cent area under the crop in the Union to the total area in the Union
Crop						
Paddy	(*a*)	1	1	—	315	
	(*b*)	51	24	0·8		
	(*c*)	0·1	1	—		22·9
Wheat	(*a*)	—	1	1	236	
	(*b*)		14	4		
	(*c*)		2	0·7		7·3
Jowar	(*a*)	—	—	—	84	
	(*b*)		7	24		
	(*c*)		0·6	2		12·2
Maize	(*a*)	—	—	—	39	
	(*b*)		2	—		
	(*c*)		0·7	—		2·6
Bajra	(*a*)	—	—	—	11	
	(*b*)		0·2	30		7
	(*c*)		—	5		
Potatoes	(*a*)	—	—	—	50	
	(*b*)	—	—			
	(*c*)	—	0·7			0·1
Sugarcane	(*a*)	—	—	—	220	
	(*b*)	—	0·2	0·2		
	(*c*)	—	0·1	0·1		
Cotton	(*a*)	—	—	—	108	1·4
	(*b*)		—	12		
	(*c*)		—	3		4·2
Total number of experiments reported		2	2	1		

--- in the case of number of experiments indicates absence.
— in the case of area under a crop indicates less than 0·1.
Blank space indicates either the corresponding figures are not available or the crop is not grown.
(*a*) No. of experiments conducted on the crop.
(*b*) Per cent area under the crop to the total cropped area in the State.
(*c*) Per cent area under the crop in the State to the total area under the crop in the Union.

that on wheat. In Punjab and Madras, no experiment was reported on *bajra*, although the area under this crop is 13 per cent and 7 per cent respectively of the total cultivated area in these States. The area under sugarcane is 1 per cent in Bihar, but 71 per cent of the experiments were devoted to studies on this crop and while 51 per cent of the area is under paddy, only 8 per cent of the total number of experiments were devoted to this crop. In Madhya Pradesh, the area under paddy is four times of that under wheat whereas the number of experiments planned for these crops were more or less equal.

Considering the relative distribution of experiments on a crop among different States, it is seen from Table III that whereas the area under paddy is highest in Bihar, being 17 per cent of the all-India area under paddy, only 4 per cent of the experiments on this crop were conducted in Bihar. In case of *bajra* no experiment was reported from States other than Bombay, while they contain 73 per cent of the area sown with this crop. Uttar Pradesh has 48 per cent of the area under potatoes in the Union whereas the number of experiments reported by this State was only nine compared to 50 conducted in the Union. It is also seen that Uttar Pradesh and Bihar contribute 59 per cent and 9 per cent respectively to the total area under sugarcane in the country, while the number of experiments on this crop in these States is 14 and 121 respectively compared to the total of 220 experiments reported on this crop. Punjab has only 2 per cent of the area under cotton while Bombay has 22 per cent, but the number of experiments on this crop is the same in these two States.

The observed disproportion of the amount of effort spent on various crops may be due to various factors, the relative economic importance of the crop and the existence or otherwise of an authority, e.g. a Commodity Committee specially interested in promoting research on it are among them. The lack of suitably located experimental centres for enlarging experimentation on certain crops has been suggested as another possible factor. The distribution of experimental stations in various States is shown in Fig. 1 p. 477. This distribution of experimental stations in various States was also studied in conjunction with the distribution of area under different crops and seems to support the view that lack of experimental stations is not a serious limitation to experimentation on certain crops.

Classification of experiments with more than ten plots according to manurial and cultural treatments

Out of the total number of 1533 experiments conducted at the research stations, there were 1344 experiments (excluding 130 experiments on crop rotations and mixed crops) each having ten or more plots. Table IV gives cropwise distribution of these experiments according to (i) purely manurial, (ii) manurial-*cum*-cultural and (iii) purely cultural. Purely manurial experiments include experiments involving quantities, time and methods of application of fertilizers, lime and gypsum, minor elements, green manure, etc. Experiments under purely cultural practices include those

TABLE IV

*Classification of experiments with more than ten plots under each crop as manurial, manurial-*cum*-cultural and cultural*

Crop	Manurial	Manurial-*cum*-cultural	Cultural
Paddy	234	21	42
Wheat	138	53	38
Jowar	*48*	*4*	*25*
Maize	30	3	5
Bajra	*8*	—	*3*
Other cereals	17	2	6
Pulses	13	—	26
Oilseeds	30	3	24
Potatoes	32	6	12
Sugarcane	154	27	30
Cotton	47	28	30
Vegetables	13	1	11
Spices	8	—	7
Tubers (other than potatoes)	4	—	7
Fruits	16	3	24
Tobacco	22	11	6
Tea	1	1	1
Coconuts	5	—	8
Jute	10	2	8
Fodder	19	12	5
Total	849	177	318

involving seedrates, seed soakings, irrigations, pre-cropping, etc. In paddy, maize and *bajra*, the number of experiments reported for testing manurial requirements was 74 per cent, 77 per cent and 73 per cent respectively while in the case of *jowar* and wheat it is 57 per cent and 58 per cent respectively of the total number of experiments on these crops. Further in wheat a number of experiments of the manurial-*cum*-cultural type were also conducted. In case of *jowar* and *bajra*, the number of experiments conducted for testing the efficacy of different cultural practices was 30 per cent and 27 per cent respectively. It is also seen that in sugarcane the experiments were mostly manurial while in cotton all the three types of experiments were equally frequent. In oilseeds, vegetables, spices and fruits both manurial and cultural experiments were equally frequent. In pulses the interest was mainly on cultural practices whereas in fodder more stress was laid on testing the combination of manurial and cultural practices. It is clear that the tendency is to plan separate experiments for study of manures and other cultural practices rather than study them simultaneously.

In the above classification only a broad idea of the character of the experiments is indicated by showing the proportion of manurial and cultural experiments. In order to assess the relative amount of experimentation done for studying the effects of different treatments, the frequencies with which treatments occurred in the experiments have been compared with the help of Table V. It is seen from the table that nitrogen, phosphorus and potash were tested in 40 per cent, 26 per cent and 7 per cent respectively of the total number of experiments excluding mixed crops and rotations. Among organic nitrogenous manures, the effects of green manure, farm-yard manure and oil cakes were studied in 9 per cent, 11 per cent and 9 per cent respectively of the total number of experiments. It is seen that while 73 per cent of the experiments included the study of inorganic fertilizers, the effects of organic manures were tested only in 29 per cent of the experiments. The study of the effects of mixed organic and inorganic fertilizers was conducted in 10 per cent of the total number of experiments. Under cultural practices, spacing and plant density and time and method of sowing and planting were each tried in 11 per cent of the total number of experiments. The effects of irrigation and minor elements were each studied in only 5 per cent of the cases showing the need for larger experimentation on irrigation.

Scoring technique of analysis

So far the relative importance of the treatments was studied only on the basis of the number of experiments in which they have been tested but this is not very satisfactory since the total amount of information available on various treatments should be the guiding factor in judging their relative importance. It can happen that the available information on a treatment may be less as compared to another which has been studied less frequently. The reason in this would be that the experiments in which the latter treatment is involved have been planned more efficiently. Number of treatments, number of levels at which each treatment is

TABLE V

Treatmentwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras	Bihar	Madhya Pradesh
Treatment—						
N	35	89	116	45	61	61
P	80	60	43	32	43	17
K	19	5	9	8	28	—
Oil cakes	18	19	12	12	14	24
Farm-yard manure	27	13	32	15	5	11
Compost	12	7	3	13	—	6
Green manure	29	17	9	31	3	10
Other organic manures	2	2	2	13	8	7
Mixed organic and inorganic manures	35	19	11	20	29	1
Lime and gypsum	1	15	2	13	15	3
Minor elements	19	18	—	1	17	—
Method of applying artificials and organics	14	6	23	19	4	13
Time of applying artificials and organics	6	16	16	4	1	7
Residual effect of fertilizers	13	—	1	4	—	5
Seed treatments	12	—	1	4	—	8
Seedrate	40	15	3	3	—	5
Seedsize	1	1	—	—	—	—
Plant material	5	—	1	3	—	—
Nursery conditions	9	—	3	1	—	—
Time and method of sowing and planting	16	27	27	16	10	4
Spacing and plant density	49	9	19	11	13	16
Irrigations	3	29	16	6	12	—
Cultural practices (including cultivations, weeding, etc.)	21	8	15	9	3	1
Time and method of harvesting	—	3	4	1	—	—
Ratooning	1	—	1	1	—	—
Effect of previous cropping	3	6	3	5	2	1
Total number of experiments reported	268	178	179	160	170	95

TABLE V—*contd.*

Treatmentwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	West Bengal	Hyderabad	Mysore	Madhya Bharat	Orissa	Assam
Treatment—						
N	14	6	17	6	4	9
P	10	7	5	7	4	1
K	2	—	1	—	1	—
Oil cakes	1	—	—	3	1	5
Farm-yard manure	4	1	1	2	1	—
Compost	1	1	—	3	—	3
Green manure	1	5	1	2	—	—
Other organic manures	1	—	3	2	—	9
Mixed organic and inorganic manures	5	15	2	—	1	—
Lime and gypsum	5	—	3	—	—	—
Minor elements	—	—	7	—	—	—
Method of applying artificials and organics	4	4	2	—	—	—
Time of applying artificials and organics	—	4	9	—	1	—
Residual effect of fertilizers	—	—	—	1	—	4
Seed treatments	3	1	—	2	—	—
Seedrate	2	5	—	—	—	—
Seedsize	1	—	—	—	—	—
Plant material	8	—	—	—	1	—
Nursery conditions	—	—	—	—	—	—
Time and method of sowing and planting	9	3	3	3	3	1
Spacing and plant density	8	4	4	—	3	—
Irrigations	—	—	—	—	—	—
Cultural practices (including cultivations, weeding, etc.)	3	—	—	—	—	—
Time and method of harvesting	—	—	—	—	—	—
Ratooning	—	—	—	—	—	—
Effect of previous cropping	—	—	—	2	—	—
Total number of experiments reported	49	32	30	17	16	16

TABLE V—*contd.*

Treatmentwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	Pepsu	Ajmer	Travancore-Cochin	Bhopal	Coorg	Vindhya Pradesh	Saurashtra
Treatment—							
N	6	2	3	1	1	1	—
P	—	2	5	1	2	1	—
K	—	—	2	—	—	—	—
Oil cakes	1	—	2	—	1	—	—
Farm-yard manure	2	—	—	—	1	1	1
Compost	—	—	—	—	—	—	—
Green manure	1	—	—	—	1	—	1
Other organic manures	—	—	—	—	—	—	—
Mixed organic and inorganic manures	—	1	5	—	—	1	—
Lime and gypsum	—	—	—	—	1	—	—
Minor elements	—	—	—	—	—	—	—
Method of applying artificials and organics	—	—	—	—	—	—	—
Time of applying artificials and organics	—	—	—	—	—	1	—
Residual effect of fertilizers	—	1	—	—	—	—	—
Seed treatments	—	—	—	—	—	—	—
Seedrate	—	2	—	5	—	—	—
Seedsize	—	—	—	—	—	—	—
Plant material	—	—	—	—	—	—	—
Nursery conditions	—	—	—	—	—	—	—
Time and method of sowing and planting	4	2	—	—	—	—	—
Spacing and plant density	1	—	—	—	—	—	—
Irrigations	4	—	—	—	—	—	—
Cultural practices (including cultivations, weeding, etc.)	—	—	3	—	—	—	—
Time and method of harvesting	—	—	—	—	—	—	—
Ratooning	—	—	—	—	—	—	—
Effect of previous cropping	1	—	—	—	—	—	1
Total number of experiments reported	13	10	10	6	2	2	1

TABLE V—*contd.*

Treatmentwise distribution of experiments for the States and Central Research Institutes

State/Central Institute	I.A.R.I.	C.P.R.I.	C.T.R.I.	C.J.R.S.	C.R.R.I.	C.C.R.S.	Total
Treatment—							
N	40	17	13	10	9	—	566
P	24	14	2	3	1	—	364
K	10	10	1	3	1	—	100
Oil cakes	7	8	2	—	—	—	130
Farm-yard manure	12	11	5	3	—	—	148
Compost	1	—	—	2	2	—	54
Green manure	6	1	—	—	2	—	120
Other organic manures	2	1	—	3	1	—	46
Mixed organic and inorganic manures.	5	—	5	2	—	—	157
Lime and gypsum	—	1	—	—	1	—	60
Minor elements	4	—	—	—	1	1	68
Method of applying artificials and organics	14	3	3	—	3	—	112
Time of applying artificials and organics	3	3	2	2	2	—	77
Residual effect of fertilizers	2	—	1	—	—	—	33
Seed treatments	2	—	—	—	—	—	33
Seedrate	3	—	—	2	—	—	85
Seedsize	—	3	—	—	—	—	6
Plant material	—	—	—	—	—	—	18
Nursery conditions	1	—	—	—	—	—	14
Time and method of sowing and planting	12	3	3	—	2	—	148
Spacing and plant density	3	—	5	5	—	—	150
Irrigations	2	1	—	—	—	—	73
Cultural practices (including cultivations, weeding, etc.)	9	—	7	—	1	1	36
Time and method of harvesting	—	1	—	4	—	—	13
Ratooning	—	—	—	—	—	—	3
Effect of previous cropping	1	—	1	—	1	—	27
Total number of experiments reported	70	23	22	19	13	2	1403

control, number of replications and type of design are some of the important factors influencing the information available from an experiment. In order to compare the information available on the various treatments, it would be necessary to devise a suitable measure of the amount of information obtained in an experiment on a given treatment. This measure or index should be such as would give due importance to the various factors contributing to the information obtained from the experiment. A study in this direction was first made by Dr. D. J. Finney in 1934 in examining the present material. He suggested a scoring technique on the basis of which the amount of information contained in an experiment with respect to a particular treatment is quantitatively assessed by assigning a score to that treatment. Besides this, two other systems of scoring are being considered. A description of their relative merits is given below.

System I: The basis of scoring is that uncontrolled experiments, as also those with two or three plots or those in which simultaneous changes in several components of treatments prevent the estimation of any plot responses, are rejected. In other words, all those experiments in which it is not possible to estimate directly any of the several components of a treatment by treatment differences are rejected. For example an experiment with the following four treatments irrespective of the number of replications and design will be rejected.

Treatments :

(i) control (no manure)

(ii) 20 lb. N+40 lb. P_2O_5

(iii) 50 lb. N+80 lb. P_2O_5+20 lb. K_2O

(iv) 20 lb. N+20 lb. P_2O_5+30 lb. K_2O

In general experiments without control plots unless the levels tested are such as to give interesting comparisons and also investigations such as trials of soil analyses are rejected, e.g. if there are two experiments, sufficiently replicated and randomised with the following treatments :

Experiment I

20 N and 40 N through ammonium sulphate

Experiment II

20 N, 40 N, 60 N and 80 N through ammonium sulphate

The first experiment will be rejected while the second will be scored. It can be seen that even though there is information on nitrogen in both the cases it is possible to study the response curve in the latter and not in the former. Each acceptable experiment is regarded as a factorial in the various factors under study. Each factor on which information with regard to some simple effects is available in the experiment receives a score of 1/ irrespective of the number of levels of the

factor and the size of the experiment. The score of 12 for each scorable main is then distributed among the different treatments comprising the factor mainly in proportion to the number of independent linear comparisons giving pure responses on each treatment.

For example in an experiment reported on sugarcane to study the effect of varying doses of nitrogen in the form of ammonium sulphate and chilesalpetre in the presence and absence of farm-yard manure and lime, the treatments were all possible combinations of :

Main-plot treatments	*Sub-plot treatments*
(i) No manure	(i) No manure
(ii) Lime 1100 lb./acre	(ii) Ammonium sulphate 100 lb. N/acre
(iii) Farm-yard manure equivalent to 50 per cent of N out of the respective doses of the sub-plots	(iii) Soda nitrate 100 lb. N/acre
	(iv) Ammonium sulphate 200 lb. N/acre
	(v) Soda nitrate 200 lb. N/acre

The design adopted was a split-plot design with four replications. Since the experiment randomised, consists of more than ten plots for both main-plot and sub-plot treatments separately and as also the estimation of pure responses is possible, the experiment is scorable. The score will be 12 for the main-plot treatments which will be distributed equally among lime and farm-yard manure, each receiving a score of six since the number of independent comparisons providing information on each treatment is the same. Similarly the score of 12 allotted to sub-plot treatments will be distributed equally among ammonium sulphate and chilesalpetre.

System 2 : In this system also unrandomised experiments as well as those with ten or fewer plots or those for odd investigations such as trials of soil catalysts are rejected. In each experiment all the plots (except control) which give pure responses or interactions of the factors under investigation will be considered for scoring. A control plot for the purpose of scoring is defined as one with no treatments under comparison or with basal treatments. In case there is no control plot in this sense, the scoring for each randomised block for each factor is based on the number of linearly independent* comparisons in pairs of plots giving the information on 'simple effects' (that is effects of single components of a treatment) of that factor and the score for the factor for each experiment is found by adding the scores for different blocks. If there are two treatments, say 20N and 40N under test then the comparison (40N-20N) involving a pair of plots is said to be a simple effect while a comparison such as (80N+20P)-(40N+80P) is not a simple effect. Scoring based on the number of linearly independent comparisons is also applicable to experiments with control plots. For example in the case of a

*A set of comparisons is said to be linearly independent if no comparison can be expressed as a linear combination of the remaining ones.

randomised block design for the study of response to nitrogen and phosphorus at three levels each, with all possible combinations in r replications ($r>1$), each factor receives a score of 6r marks. Since the effect of nitrogen is obtained from two independent comparisons at each level of phosphorus, totalling to six comparisons and in each replication the same amount of information is obtained, the score will be 6r. Similar is the case with phosphorus. For example if the levels of N and P are :

Nitrogen	*Phosphorus*
0 lb. N	0 lb. P_2O_5
20 lb. N	20 lb. P_2O_5 =9 treatments
40 lb. N	40 lb. P_2O_5

The comparisons in pairs of plots giving information on 'simple effects' on nitrogen for a single replication, are :

(i) (20 N + 0 P_2O_5)—(0 N + 0 P_2O_5)
(ii) (40 N + 0 P_2O_5)—(0 N + 0 P_2O_5)
(iii) (20 N + 20 P_2O_5)—(0 N + 20 P_2O_5)
(iv) (40 N + 20 P_2O_5)—(0 N + 20 P_2O_5)
(v) (20 N + 40 P_2O_5)—(0 N + 40 P_2O_5)
(vi) (40 N + 40 P_2O_5)—(0 N + 40 P_2O_5)

Similarly, there will be six comparisons for phosphorus. It can be seen that the above six comparisons are linearly independent. The scores in a factorial design by this method are in proportion to the number of degrees of freedom of each factor and the number of replications. Further any contrast that can be formed with these treatments will be a linear function of the above comparison and thus will not be linearly independent of the above comparisons. Thus the above comparisons provide all the information contained in the experiment.

System 3 : This system of scoring differs from system 2 in that the effective number of replicates for scoring is taken as the square root of the number of replications in which the treatments were actually tried. Thus in the example considered above, the score for each of the factors will be $6\sqrt{r}$.

Comparison of the three systems of scoring : It can be seen that in the first system of scoring every factor in an experiment if it is scorable receives 12 points irrespective of the number of levels and number of plots on which the information is based for that factor. For example, an experiment with two factors, i.e., nitrogen and phosphorus, each at two levels (say, 0 and 30 lb.) receives 12+12=24 points and a so another experiment with the same two factors each at three levels receives the same score. It is obvious that there is more information in the latter case compared to the former, since we can have a better idea of the response curve from the latter and can also estimate the optimum dose. Likewise, no consideration is given in allotting points to experiments with a large number of plots. In comparison,

the second system of scoring takes into consideration the number of levels of the factor involved, a complete factorial or an incomplete factorial (not involving the full set of factorial combinations) and the number of plots utilized. The scoring in a factorial design by the second system is in proportion to degrees of freedom for each factor and the number of replications, which is not the case in the first system. Also proportionate consideration depending on the number of levels of each factor is being given to the information available on interaction whereas in the earlier system it was not so. Further, the element of subjectiveness in the first system of scoring involved in the rejection of experiments yielding no pure responses and in the distribution of scores allotted to each factor into different treatment classifications has been got over in the second system of scoring. In this sense the second method of scoring can be considered superior to the first system of scoring. But the latter system of scoring suffers from the defect that experiments having too many replications receive excessive scores. This defect is eliminated in the third system of scoring. Further, by taking the square root of the number of replications as the number of effective replications for scoring, it can be said that the system takes into consideration the precision of the information provided by the experiment on the treatment effects. Thus the third system of scoring is preferable to the other two systems and the subsequent discussion of the relative amount of information on various treatments will be based on the scores given to the treatments under the third system only.

Scoring under system 1 will in general give a different picture of the relative importance of various treatments when compared to that under the other two systems, except, in the case wherein the treatments under comparison occurred in the same experiments which are symmetrical factorial experiments. This system cannot be adopted as a substitute for the other two, even though it is more rapid. Considering for example, all the experiments reported under paddy in Punjab State giving information on nitrogen and spacing and plant density it is seen from the scores given below under the three systems how the first system of scoring gives a different picture.

	Nitrogen	Spacing and plant density
System 1	88	24
System 2	218	198
System 3	104	109

Looking at the scores under the first system one is led to believe that the experiments provided relatively more information on nitrogen than on spacing and plant density while the scores under the other two systems do not reveal the same. But in fact on further examination of the experiments on these two treatments, it is seen that the number of plots (293) providing information on nitrogen from the eight experiments involving it, is nearly equal to the number of plots

(297) providing information on spacing and plant density from the two experiments planned with it. Naturally, we expect the scores to be nearly equal as the score is an index of information. On the basis of the above reasoning it is not incorrect to say that the second and third systems are better informative than the first system.

Assessment of the Relative Amount of Information on Various Treatments

In order to have an over-all picture of the information obtained on various treatments from the experiments reported all over India scores were pooled over all the States and the crops. A similar type of pooling over treatments was not possible in view of the fact that scores are not additive over different treatments.

It was observed that among inorganic fertilizers the scores for nitrogen, phosphorus and potash are 8163, 6166 and 2192 respectively while the number of experiments in which these treatments were tested was 566, 364 and 100 respectively. Under cultural practices spacing and plant density and time and method of sowing and planting received a score of 2634 and 2520 respectively. The amount of information on time and method of sowing and planting is more than twice that on farm-yard manure, even though the number of experiments in which these treatments were tested is the same, i.e. 148. The information on green manure is less than that on lime and gypsum while the number of experiments in which green manure was tested is twice that in which lime and gypsum was tested.

In most of the crops the information available is mostly on nitrogen and phosphorus among fertilizers and time and method of sowing and planting and spacing and plant density among cultural practices. Excepting in the case of paddy and wheat very little information is available on the effects of fertilizers such as compost, green manure, etc.

In view of the earlier observation made while discussing the proportion of experiments devoted to each crop, the distribution of the scores for treatments and States were obtained for the important crops, viz. paddy, wheat, *jowar*, sugarcane, cotton, potatoes, oilseeds and tobacco and have been presented in Tables VI to XIII. Similar tables were also prepared for other crops but have not been presented here. However, a discussion based on the scores relating to all crops is presented below.

Paddy

In Bombay, phosphorus received the highest score being 264 and in comparison with nitrogen, the information on the former is thrice that on nitrogen. Among organic manures, the information on farm-yard manure is nearly twice that on green manure while there is very little information on the effect of compost. Under cultural practices spacing and plant density received the highest score being twice that on time and method of sowing and planting.

In Uttar Pradesh, the score for nitrogen and phosphorus is 426 and 291 respectively. Further the information on the effect of lime and gypsum is twice of that on minor elements. Under cultural practices time and method of sowing and planting received 1·6 times the score for spacing and plant density.

In Punjab, nitrogen received a score of 103 while under cultural practices the score for spacing and plant density was 109. In Madras, the information on lime and gypsum and potash is equal while one experiment on phosphorus is equal to 1·7 experiments on nitrogen in terms of information.

In Madhya Pradesh, nitrogen received 1·6 times the score on phosphorus whereas in West Bengal the score for phosphorus is 1·8 times that of nitrogen. Further, the information on lime and gypsum is considerably large when compared to other treatments.

On the whole it can be seen that the amount of information on nitrogen and phosphorus is nearly the same and that on method of application is 1·6 times to that on time of application of artificials and organic manures. It is also seen that except in Madras and a little in Bihar no information is available on the effect of potash in the other States. Among cultural practices the information on time and method of sowing and planting is 1·2 times to that on spacing and plant density.

Wheat

In Uttar Pradesh and Punjab the information on nitrogen is more than twice that on phosphorus whereas at the Central Institute, it is three times that on phosphorus. Under cultural practices, the information on time and method of sowing and planting, seedrate and irrigations is in the ratio 2·4 : 1 : 1. On the whole there is more information on nitrogen than on phosphorus (being 1·7 times to that on phosphorus), while little information is available on potash. Among cultural practices, time and method of sowing and planting and seedrate recorded nearly equal amount of information.

Jowar

In Bombay, phosphorus received the highest score, being 302 and nitrogen only 24. In Madhya Pradesh, the information on nitrogen is 5·5 times that on phosphorus. Under cultural practices the information on spacing and seedrate is equal. On the whole, the amount of information on phosphorus is more than that on nitrogen while under cultural practices it is nearly equal on seedrate and spacing.

Sugarcane

In Bombay State the information available on phosphorus is four times that on potash. Among organic manures, compost received the highest score. Under cultural practices the amount of information on spacing and plant density is 3·5 times that on irrigation. The information on nitrogen in Uttar Pradesh is 1·7 times that on phosphorus while there is no information on nitrogen in Bombay. Also time of application of artificial and organic manures received 12 times the score for method of application. In case of Punjab, the information on nitrogen, phosphorus and potash is in the ratio of 1·6 : 1·4:1. It is seen that over all the States nitrogen obtained three times the score of phosphorus. Under cultural practices, time and method of sowing and planting received the highest score being 567.

TABLE

Treatmentwise distribution of scores for

Crop: Paddy

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras	Bihar	Madhya Pradesh	West Bengal
Treatment							
N	86	426	103	230	15	89	144
P	264	291	37	393	21	57	263
K	0	..	..	200	11	..	..
Oil cakes	62	4	4	11	..	49	..
Farm-yard manure	177	80	..	12	4	2	95
Compost	24	33	..	38	..	20	..
Green manure	92	4	4	96	0	24	8
Other organic manures	..	..	..	30	2	22	..
Lime and gypsum	17	229	..	202	6	..	137
Minor elements	..	110	..	..	37	..	..
Method of applying artificials and organics	27	..	10	81	..	18	18
Time of applying artificials and organics	11	..	17	0	..	..	..
Residual effect of fertilizers	150	..	..	15	..	20	..
Seed treatments	44	..	..	..	..	..	..
Seedrate	38	..	..	..	..	..	..
Nursery conditions	217	..	18	5	..	..	..
Time and method of sowing and planting	133	188	40	39	..	40	90
Spacing and plant density	245	115	109	5	..	4	61
Cultural practices	122	34	..	6	2	..	..
Effect of previous cropping	..	..	..	7	..	..	..

VI

paddy for the States and Central Institutes

Hyderabad	Mysore	Madhya Bharat	Orissa	Assam	Travancore-Cochin	Coorg	Vindhya Pradesh	Central Institutes	Total
38	49	18	4	17	8	10	32	313	1,582
63	10	28	11	..	32	55	4	126	1,655
..	..	..	..	..	..	..	..	120	331
..	..	18	..	7	12	10	..	..	177
..	..	..	8	..	..	10	4	48	440
..	..	..	..	4	..	..	..	36	155
24	..	..	..	..	..	10	..	40	302
..	..	..	..	25	..	..	..	23	111
..	13	..	..	..	..	..	..	12	616
..	81	..	..	..	..	..	..	30	258
10	2	..	..	..	..	..	..	56	222
54	28	..	..	..	..	..	16	16	142
..	..	..	..	27	..	..	..	..	212
..	..	..	..	..	..	..	..	..	44
29	..	..	..	..	..	..	..	..	67
..	..	..	..	..	..	..	..	4	244
..	0	..	..	..	..	..	..	105	635
..	..	..	..	..	..	..	..	..	539
..	..	..	..	..	..	..	..	..	164
..	..	..	..	..	..	..	..	16	23

TABLE

Treatmentwise distribution of scores for

Crop : Wheat

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Bihar	Madhya Pradesh
Treatment					
N	7	629	409	..	239
P	57	309	178	..	202
K	..	31	0	..	..
Oil cakes	..	101	..	..	28
Farm-yard manure	15	17	10	..	2
Compost	32	..	..	..	5
Green manure	41	99	7	..	..
Other organic manures	..	..	..	..	7
Lime and gypsum	..	60	..	..	26
Minor elements	33	38	..	..	..
Method of applying artificials and organics	6	55	63	..	..
Time of applying artificials and organics	24	170	28	..	..
Residual effect of fertilizers	..	..	6	..	8
Seed treatments	38	..	..	..	14
Seedrate	99	155	26	..	28
Time and method of sowing and planting	..	384	4	..	..
Spacing and plant density	45	18	73	..	17
Irrigations	24	152	3	30	..
Cultural practices	20	7	5	..	..
Effect of previous cropping	16	85	5	17	..

NOTE.—One experiment each was reported from V indhya

VII

wheat for the States and Central Institutes

Hyderabad	Madhya Bharat	Pepsu	Ajmer	Bhopal	Central Institutes	Total
..	34	4	20	13	280	1,635
8	66	..	10	13	94	937
..	..	..	..	..	14	45
..	..	..	0	..	10	139
..	..	4	0	..	60	110
..	..	..	0	..	..	37
12	44	4	..	..	19	231
..	..	..	0	..	32	39
..	..	..	..	..	..	86
..	..	..	..	..	..	71
4	..	..	..	..	31	159
..	..	..	..	..	21	243
..	..	..	29	..	27	70
..	51	..	..	..	..	103
..	..	..	16	56	13	393
..	6	..	24	..	11	429
..	..	..	..	..	..	152
..	..	..	..	..	25	234
..	..	..	..	..	78	110
..	..	4	..	..	..	129

Pradesh and Saurashtra, the scores were zero and nine respectively.

TABLE

Treatmentwise distribution of scores for

Crop : *Jowar*

State/Central Institute	Bombay	Uttar Pradesh	Madras
Treatment			
N	24	132	19
P	302	132	13
Oil cakes	182	..	19
Farm-yard manure	121	..	27
Compost	32	..	7
Green manure	44	..	..
Minor elements	18	..	..
Method of applying artificials and organics	..	..	..
Time of applying artificials and organics	0	..	..
Residual effect of fertilizers	53	..	16
Seed treatments	78	..	..
Seed rate	123	..	..
Time and method of sowing and planting	41	..	..
Spacing	43	..	..
Cultural practices	221	..	..
Effect of previous cropping	2	..	..

NOTE.—One experiment was reported

VIII

jowar *for the States and Central Institutes*

Madhya Pradesh	Hyderabad	Madhya Bharat	Central Institutes	Total
116	..	32	..	323
21	..	..	..	468
22	..	..	..	223
5	..	..	..	153
5	..	..	..	44
..	..	..	..	44
..	..	..	..	18
11	..	..	..	11
..	..	..	..	0
36	..	18	..	123
11	..	..	..	89
75	6	..	..	204
..	..	20	10	71
79	58	..	..	180
5	..	..	..	226
..	..	8	..	10

from Punjab and the score was zero.

TABLE

Treatmentwise distribution of

Crop : Sugarcane

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras
Treatment				
N	0	87	169	51
P	128	50	146	..
K	32	36	108	..
Oil cakes	..	7	29	2
Farm-yard manure	7	4	6	2
Compost	116	3	22	0
Green manure	2	19	..	5
Other organic manures	..	6	..	0
Lime and gypsum	0	..	2	..
Minor elements	..	0	..	..
Method of applying artificials and organics	69	5	16	2
Time of applying artificials and organics	..	59	2	25
Residual effect of fertilizers	..	..	..	..
Seed treatments	4	..	8	..
Plant material	10	..	4	8
Time and method of planting	..	13	24	43
Spacing	71	..	4	7
Irrigations	20	4	16	6
Cultural practices	..	5	..	0
Time and method of harvesting	..	11	..	24
Ratooning	..	..	4	..
Effect of previous cropping	..	..	1	..

IX

scores for sugarcane for the States and Central Institutes

Bihar	West Bengal	Mysore	Orissa	Assam	Central Institutes	Total
1,038	..	4	7	6	121	1,483
100	15	7	..	..	31	477
76	..	..	..	..	..	252
104	..	..	7	..	..	149
..	..	..	..	..	..	19
..	..	..	..	..	..	141
12	..	..	..	..	..	38
56	..	..	..	6	..	68
..	..	4	..	..	..	6
..	..	..	..	..	25	25
39	7	4	..	..	16	158
15	..	..	10	..	..	111
..	..	..	..	12	..	12
..	..	..	..	..	..	12
..	..	..	..	..	..	22
487	..	..	..	..	..	567
112	.	..	..	..	..	194
64	..	..	..	..	..	119
24	..	..	..	..	..	29
..	..	..	..	..	..	35
..	..	..	..	..	..	4
..	..	..	..	..	..	8

Cotton

In Bombay, phosphorus received the highest score among fertilizers and in comparison to nitrogen it is 1·4 times. Under cultural practices spacing and plant density received the highest score. In Uttar Pradesh, the amount of information on nitrogen and farm-yard manure is equal, while in Punjab the information on the latter is 16 times that on nitrogen. In Madras, nitrogen received the highest score while almost no information is available on phosphorus. Under cultural practices, the information available on spacing and plant density and effect of previous cropping is nearly equal. The experiments reported from Madhya Pradesh provided information on nitrogen equal to 1·1 times to that on spacing and plant density. In Mysore and Hyderabad, the scores on spacing and plant density were 218 and 27 respectively. The information on seed treatments is more in Madhya Bharat when compared to other States. The overall picture is that the information on nitrogen is 2·4 times that on phosphorus. Under cultural practices, spacing and plant density received the highest score.

Potatoes

In Madras, the scores for nitrogen and phosphorus are equal being 40 each, whereas lime and gypsum received a score of 48. In Uttar Pradesh, the informatson on phosphorus is 1·1 times that on nitrogen while under cultural practices spacing received a score of 62. The amount of information on spacing is dounle that on seedsize in West Bengal. It can be seen that at Central Institutes the information on nitrogen, phosphorus and potash is in the ratio of 1·3 : 1·1: 1. Among cultural practices, the information on time of lifting is nearly three times that on spacing.

Oilseeds

In Bombay, information is available only on phosphorus among fertilizers. The information on minor elements constituted the major part. Under cultural practices seed rate received three times the score for spacing and plant density. In Punjab phosphorus and nitrogen received 76 and 39 score respectively. Under cultural practices the information is mostly on spacing and plant density. Phosphorus and potash obtained equal scores in Madras and Bihar. In Bihar, the information on lime and gypsum is equal to that on phosphorus. On the whole, the amount of information on phosphorus, nitrogen and minor elements is in the ratio of 1·7 : 1 : 1·2.

Tobacco

In Bombay, the information is mainly on cultural practices such as topping of leaves, etc. In Punjab, the total information on nitrogen is 1·6 times that on phosphorus while there is no information on the effects of green manure. Among cultural practices only time and method of planting and nursery conditions were studied, the information on the latter being double that on the former. Central institutes provided major portion of the total information available in the Union. The amount of information on nitrogen is the highest, the score being 216, while on phosphorus and potash it is nearly equal. Under cultural practices, time and

method of sowing and planting received 1·3 times the score for spacing and plant density.

Other crops

The experiments on maize provided information mainly on nitrogen and minor elements, the latter receiving the highest attention. Most of the experiments on *bajra* were reported from Bombay where oil cakes received the highest score being 96 while phosphorus received 84. In case of tubers the information is available mostly on nitrogen, phosphorus and potash. With regard to pulses the information in Bombay is mainly on minor elements, being 72 per cent of the total information available over all the States for this treatment while in Punjab the total information on time and method of sowing and planting is 1·8 times that on irrigation. Bombay contributes most to the information on spices, scores for nitrogen, potash and phosphorus being equal. Experiments on vegetables reported from Bombay and Punjab provided information mainly on nitrogen, phosphorus and potash.

Experiments on fodder provided information mainly on nitrogen and phosphorous. In Bombay, the effects of different seedrate were also studied. With respect to experiments on fruits, the information is mainly on the manurial requirements of the trees except in Bombay and West Bengal where considerable amount of work has been done on the study of different planting materials. Eleven experiments were scored out of fifteen reported and the information obtained from them was mostly on minor elements. Only Central Institutes reported experiments on jute, and various aspects of this crop are being investigated. Punjab reported a few experiments on tea.

Fractional loss of information

As mentioned earlier, only those pairs of plots which provided pure responses or simple effects on the factors tested were considered for scoring. It was observed while scoring that some pairs of plots did not provide any pure responses or simple effects. That is, if a better choice of the treatments was made it would have been possible to obtain more information with the same number of plots. Thus there is a loss in the information by testing treatment combinations which do not contribute to pure responses. In order to study how much portion of an experiment was not effectively utilized to obtain information, each experiment was examined and the loss of information was estimated. The fraction lost is estimated as the ratio of the difference between the score that would have been obtained minus the score actually recorded to the total score that would have been obtained for a single replicate. An experiment is said to be a complete loss if no comparison provides information on simple effects. For example an experiment with the following treatments will be said to be a complete loss :

(i) Control
(ii) 20 lb. N+10 lb. $P_2 0_5$
(iii) 40 lb. N+20 lb. $P_2 0_5$
(iv) 80 lb. N+40 lb. $P_2 0_5$

TABLE

Treatmentwise distribution of scores for cotton

Crop : Cotton

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras
Treatment				
N	76	30	237	112
P	105	..	72	3
K	64	..	..	..
Oil cakes	37	..	15	6
Farm-yard manure	6	30	16	9
Compost	..	..	2	..
Green manure	..	..	..	9
Other organic manures	30	..	..	12
Method of applying artificials and organics	6	..	23	2
Time of applying artificials and organics	..	..	17	..
Residual effect of fertilizers	48	..	..	16
Seed treatments	27	..	..	..
Seedrate	35	..	..	..
Time and method of sowing and planting	..	..	20	12
Spacing and plant density	124	..	50	48
Irrigations	..	..	12	..
Cultural practices	21	7	..	..
Effect of previous cropping	..	..	..	50

X

for the States and Central Institutes

Madhya Pradesh	Hyderabad	Mysore	Madhya Bharat	Pepsu	Central Institutes	Total
134	21	55	19	20	10	705
12	15	25	34	..	27	293
..	..	..	..	..	..	64
17	..	..	10	4	..	89
32	4	..	10	4	..	111
..	4	..	20	..	..	26
48	..	..	42	..	..	99
..	..	18	10	..	..	70
68	..	..	..	..	7	106
40	..	17	..	..	..	74
..	..	..	..	..	..	64
14	13	..	36	..	..	90
..	..	..	..	..	..	35
..	4	48	8	20	25	137
121	27	218	..	6	25	619
..	..	..	..	24	..	36
..	..	..	..	..	4	32
18	..	..	17	..	..	85

TABLE XI

Treatmentwise distribution of scores for potatoes for the States and Central Institutes

Crop : Potatoes

State/Central Institute	Uttar Pradesh	Madras	Bihar	West Bengal	Pepsu	Central Institutes	Total
Treatment							
N	58	40	..	..	6	767	871
P	62	40	..	..	..	680	782
K	36	..	..	..	..	601	637
Oil cakes	4	..	..	..	..	144	148
Farm-yard manure	2	..		..	..	168	170
Compost	..	..	..	7	..	..	7
Green manure	..	26	..	..	..	18	44
Other organic manures	..	2	..	..	..	8	10
Lime and gypsum	8	48	4	..	..	..	60

TABLE XI—*contd.*

Treatmentwise distribution of scores for potatoes for the States and Central Institutes —contd.

Crop : Potatoes—*contd.*

State/Central Institute	Uttar Pradesh	Madras	Bihar	West Bengal	Pepsu	Central Institutes	Total
Miner elements	..	24	4	..	..	..	28
Method of applying artificials and organics	..	12	..	..	..	39	51
Time of applying artificials and organics	..	..	..	..	..	138	138
Seed treatments	..	..	..	12	..	..	12
Seed size	15	..	..	36	..	130	181
Time and method of sowing and planting	..	..	..	..	..	30	30
Spacing	62	7	..	72	..	119	260
Irrigations	..	..	..	..	..	11	11
Cultural practices	6	..	..	..	..	4	10
Time of lifting	..	..	..	..	..	333	333

TABLE

Treatmentwise distribution of scores for oilseeds

Crop : Oilseeds

State/Central Institute	Bombay	Uttar Pradesh	Punjab	Madras
Treatment				
N	..	4	76	..
P	72	4	39	48
K	..	4	..	48
Oil cakes	..	4	..	..
Farm-yard manure	..	4	..	..
Compost	..	..	..	..
Other organic manures	..	4	..	32
Lime and gypsum	..	..	..	..
Minor elements	225	..	..	..
Method of applying artificials and organics	48	..	17	..
Time of applying artificials and organics	..	..	2	..
Residual effect of fertilizers	..	..	..	..
Seed treatments	12	..	..	..
Seed rate	132	..	6	..
Time and method of sowing and planting	..	..	6	15
Spacing and plant density	44	..	59	22
Cultural practices	..	..	..	16

XII

for the States and Central Institutes

Bihar	Madhya Pradesh	West Bengal	Madhya Bharat	Assam	Pepsu	Central Institutes	Total
4	4	..	24	29	12	32	185
112	4	..	..	2	..	36	317
112	..	..	..	..	..	..	164
..	..	..	..	9	..	8	21
..	..	..	..	..	..	8	12
..	..	..	..	2	..	..	2
..	..	..	..	11	..	..	47
112	..	..	..	..	..	..	112
5	..	..	..	..	..	..	230
..	..	..	..	..	..	36	101
..	..	..	..	..	..	..	2
..	20	..	..	..	..	..	20
..	..	..	..	..	..	..	12
..	..	19	..	..	..	..	157
..	..	..	..	12	10	..	43
..	28	29	..	..	..	..	182
..	..	..	..	..	..	..	16

TABLE XIII

Treatmentwise distribution of scores for tobacco for the States and Central Institutes

Crop : Tobacco

State/Central Institute	Bombay	Punjab	Central Institutes	Total
Treatments				
N	5	90	216	311
P	..	55	65	120
K	..	26	61	87
Oil cakes	..	20	16	36
Farm-yard manure	..	20	39	59
Green manure	..	..	13	13
Method of applying artificials and organics	..	..	78	78
Time of applying artificials and organics	..	5	26	31
Residual effect of fertilizers	..	..	113	113
Nursery conditions	..	49	..	49
Time and method of planting	24	24	132	180
Spacing and plant density	..	..	105	105
Cultural practices	80	..	75	155
Effect of previous cropping	..	..	8	8

An experiment with the treatments as all possible combinations of

$$\begin{pmatrix} 0 \end{pmatrix} \quad \begin{pmatrix} 0 \end{pmatrix}$$
$$\begin{pmatrix} 20\,N + 10\,P_2O_5 \end{pmatrix} \times \begin{pmatrix} 20\,K_2O \end{pmatrix}$$
$$\begin{pmatrix} \\ 30\,N + 15\,P_2O_5 \end{pmatrix} \quad \begin{pmatrix} \\ 40\,K_2O \end{pmatrix}$$

will entail 50 per cent loss of information. An experiment like the one mentioned below will give full information on the treatments.

$$\begin{pmatrix} 0 \end{pmatrix} \quad \begin{pmatrix} 0 \end{pmatrix}$$
$$\begin{pmatrix} 20\,N \end{pmatrix} \times \begin{pmatrix} 20\,P_2O_5 \end{pmatrix}$$
$$\begin{pmatrix} 40\,N \end{pmatrix} \quad \begin{pmatrix} 40\,P_2O_5 \end{pmatrix}$$

A frequency distribution of the experiments according to the fraction of a replication lost as estimated by the above procedure is given below :

Distribution of experiments according to fractional loss

Fractional loss	Number of experiments	Percentage number of experiments
1·0000	163	12
0·8750	0	
0·7500	5	1
0·6250	4	
0·5000	30	2
0·3750	33	2
0·2500	55	4
0·1250	32	2
	30	2
0·0000	1051	75
	1403	

It is observed that as many as 163 experiments or nearly 12 per cent of the total number of experiments were a complete waste as none of the comparisons gave information on simple effects. Also, 3 per cent of the experiments reported were such in which more than half of the information was lost due to improper choice of the treatments. Further, the number of experiments with loss not exceeding half the amount of information that could be obtained was 10 per cent of the total number of experiments reported. Seventy five per cent of the experiments gave all the information that could be expected from their size.

Earlier, it was noted that 163 experiments did not provide any information on pure responses. Further examination of these experiments in conjunction with different crops has revealed that 34 per cent, 9 per cent and 6 per cent of the experiments reported on sugarcane, paddy and wheat respectively did not yield any information on pure responses. However, it may be added that the experiment which involves no loss of information need not be considered as efficiently planned in all respects.

Defects of experiments

In the course of examination of the information supplied, some shortcomings in the selection of treatments to be tested and in the layout were frequently observed. The shortcomings have been classified into a few broad categories such as lack of replication, smothering of effects by basal treatments, fixed ratios of fertilizers, failure to confound, unnecessary mixed levels, etc. Each of the experiments was critically examined and the defects were noted down by taking into consideration the possible alternative set of treatments with the same objectives and a possible alternative design.

Table XIV gives the frequency distribution of different types of shortcomings. It is seen from Table XIV that in nearly 34 per cent of the experiments either the experimenter failed to include additional factors even though there was scope for it or conducted small one-factor or two-factor experiments whereas a complete factorial experiment involving all the factors having a bearing on the problem would have given relatively more information with the same number of plots. Testing of a few selected combinations of the treatments without having all the possible combinations of the treatment constituents or using some fixed ratio of fertilizer mixtures was a defect in 17 per cent of the cases. In 12 per cent of the experiments the split-plot design was unnecessarily used while a confounded design or a randomised block design would have been better. It is also seen that in nearly 21 per cent of the cases there was an excess of replication which could have been utilised for some other investigation without much loss of precision on the effects of the treatments under comparison. In 10 per cent of the experiments either no randomisation was done or the same randomisation was repeated for more than one experiment. Further, in nearly 13 per cent of the total number of experiments the technical terms were either misunderstood or there was lack of proper description of the experiments. For example, an experiment with its plots arranged in a square

TABLE XIV

Distribution of experiments according to different defects

Defects	Number of experiments	Per cent number of experiments
Lack of replication and too small	62	4·4
Unrandomised or repetition of randomisation	140	10·0
Wrong description or lack of proper description	186	13·2
Lack of controls	134	9·6
Simple tests of complex comparisons	38	2·7
Inadequate comparisons between types	193	13·8
Smothering of effects by basal treatments	133	9·5
Fixed ratio of fertilizers or miscellaneous non-factorial combinations	244	17·4
Large blocks or failure to confound	38	2·7

TABLE XIV—*contd.*

Distribution of experiments according to different defects—contd.

Defects	Number of experiments	Per cent number of experiments
Failure to include factors	478	34·1
Unnecessary split-plots	168	12·0
Unnecessary balanced confounding	6	0·4
Unnecessary mixed levels	50	3·6
Excessive replications	290	20·7
Too many levels and extreme levels	124	8·8
Inadequate comparisons for time and method of application of fertilizers	60	4·3
Inclusion of unnecessary treatments	25	1·8
Number of experiments	1403	..

formation was reported as a 'Latin Square' or a systematic arrangement of treatments was stated to be 'randomisation'. In some cases, the terms 'basal manuring' and 'treatments under comparison' were considered synonymous. It is also observed that in 14 per cent of the cases, either only a single level of a nutrient (e g. nitrogen) apart from zero is included n experiments to compare different forms of nitrogen or organic manures especially farm-yard manure were regarded as sources of nitrogen only and experiments planned with other fertilizers on this basis. There was also a tendency to have too many levels or extreme levels and to have heavy basal manuring providing the same nutrient as that under comparison.

Experiments on Cultivators' Fields

Summarization of the data

The summarization of the data received from the States is done on the same basis as that of experiments at research stations. Table XV gives the Statewise distribution of the experiments conducted in cultivators' fields classified as those sponsored by I.C.A.R., Commodity Committees or the States themselves. It is seen that only a few States have laid great stress on conducting experiments on cultivators' fields. First come are Bihar and Uttar Pradesh which have conducted 78 per cent and 15 per cent respectively of the experiments reported. Next are Punjab and Madras with 3 per cent each. It should be noted, however, that although in West Bengal the I.C.A.R. scheme of agronomic trials on the lines of Dr. Stewart's recommendations is being conducted in cultivators' fields on paddy and jute, no information has been provided about these experiments which are about 50 in number for each of these crops. It is also observed that about 88 per cent of the total number of experiments have been undertaken by the States themselves.

In the Statewise distribution of experiments according to different crops presented in Table XVI, it is seen that over all the States, 94 per cent of the experiments reported were on cereals such as paddy, wheat, etc., while 5 per cent of the experiments were devoted to the sugarcane crop. In Bihar the experiments were mainly conducted on paddy, wheat and maize, being 44 per cent, 49 per cent, and 7 per cent respectively. In Uttar Pradesh, the experiments were spread over different crops, about 47 per cent being on wheat. In Punjab the experiments were mainly done on sugarcane.

Table XVII gives the frequency of experiments in which a particular treatment was tried in order to assess the relative amount of effort spent on studying the effects of different treatments. Of the experiments reported 98 per cent were manurial and were devoted to study the responses of different manures on paddy, wheat, *jowar*, *bajra*, barley, potatoes, vegetables and fruits while the remaining were devoted to study different cultural practices. It is seen that different fertilizer elements such as nitrogen and phosphorus were tested in 96 per cent of the total number of experiments while potash was tested in 73 per cent of the experiments. A large number of experiments, constituting about 74 per cent were devoted to a

TABLE XV

Distribution and classification of experiments on cultivators' fields

State/Central Institute	Number of experiments sponsored by			Total number of experiments reported	Per cent number of experiments reported
	I.C.A.R.	Commodity Committees	State		
States—					
Uttar Pradesh	..	39	322	361	14·7
Punjab	..	81	..	81	3·3
Madras	74	4	..	78	3·2
Bihar	98	..	1,800	1,898	77·6
West Bengal	..	7	..	7	0·3
Hyderabad	..	..	7	7	0·3
Pepsu	..	..	2	2	0·1
Travancore-Cochin	..	..	11	11	0·4
Central Institutes—					
Central Potato Research Institute	..	..	2	2	0·1
Total	172	131	2,144	2,447	100·0

study of mixed fertilizers. Further, among the experiments reported, potash was tried only in Bihar.

On further examination, it was observed that 96 per cent of the total number of experiments reported were unreplicated while only 4 per cent of the experiments were replicated. In case of sugarcane nearly 62 per cent of the experiments were replicated. It is obvious, however, that lack of replication in simple trials in cultivators' fields is not a defect in the sense that an experiment with a given set of treatments is repeated over different fields or places which in fact can be considered as replications of the experiment.

Scoring technique of analysis

In order to find out the relative amount of stress laid for studying the effects of different treatments on cultivators' fields, the scoring technique of analysis described earlier was adopted except that unrandomised experiments as also those with ten or fewer plots, were taken into consideration. Unlike in the case of experiments at research stations, both pure and mixed responses were taken into consideration for scoring. However, mixed responses formed a separate category.

The analysis revealed that in case of paddy, Uttar Pradesh, Madras and Bihar provided information, mainly on nitrogen and phosphorus, the relative information being equal in each State. Moreover, in Bihar the study of the effect of potash received considerable attention. The position is more or less the same in respect of maize. The information on wheat is mainly on nitrogen and phosphorus in all the States except in Bihar where potash also received considerable attention. Only Uttar Pradesh reported experiments on *jowar* providing information on nitrogen and phosphorus.

Experiments on sugarcane were mainly conducted for the study of responses of nitrogen and phosphorus through artificial fertilizers under cultivators' conditions. Also, the method of application of organic and inorganic manures was studied in Uttar Pradesh and West Bengal. Further, in Uttar Pradesh green manuring, time and method of sowing and planting and time and method of harvesting received considerable attention. Among all the States, only Uttar Pradesh reported a few experiments on potatoes devoted mainly to the study of responses of nitrogen and phosphorus. At the Central Potato Research Institute information is available mainly on the effects of phosphorus and potash. For other crops and fruits the information is available mainly on nitrogen and phosphorus.

The experiments were classified as randomised and unrandomised to see to what extent randomisation is practised in conducting the experiments on cultivators' fields. Table XVIII shows the classification of the experiments into replicated and unreplicated and randomised and not randomised for each State. It is seen that 87 per cent of the total number of experiments reported were not randomised, majority of which were conducted in Bihar, where only 104 experiments were randomised out of 1,898 experiments. It may be mentioned that experiments which are replicated are mostly randomised.

TABLE

Cropwise distribution of experiments conducted on

State/Central Institute	Uttar Pradesh	Punjab	Madras
Crop—			
Paddy	39	..	74
Wheat	169	..	..
Jowar	60	..	..
Maize	7	2	..
Bajra	29	..	..
Other Cereals	6	..	..
Potatoes	11	..	..
Sugarcane	40	79	4
Vegetables	..	..	..
Fruits	..	..	..
Total	361	81	78

XVI

cultivators' fields for the States and Central Institutes

Bihar	West Bengal	Hyderabad	Pepsu	Travancore-Cochin	C.P.R.I.	Total
830	..	7	..	11	..	961
937	..	..	2	..	..	1,108
..	..	..	..	..	..	60
125	..	..	..	..	..	134
..	..	..	..	..	..	29
..	..	..	..	..	..	6
..	..	..	..	..	2	13
..	7	..	..	..	..	130
4	..	..	..	..	..	4
2	..	..	..	..	..	2
1,898	7	7	2	11	2	2,447

TABLE

Treatmentwise distribution of experiments on

State/Central Institute	Uttar Pradesh	Punjab	Madras
Treatments			
N	336	34	74
P	336	18	74
K	..	..	..
Oilcakes	..	19	..
Farm-yard manure	..	2	..
Green manure	9	..	..
Mixed organic and inorganic manures	..	5	..
Minor elements	..	..	..
Method of applying artificials and organics	12	..	..
Time of applying artificials and organics	..	3	2
Time and method of sowing and planting	7	..	..
Spacing and plant density	7	8	..
Irrigations	..	14	..
Cultural practices	..	2	1
Time and method of harvesting	8	..	..
Ratoon crop	..	..	1
Total number of experiments reported	361	81	78

XVII

cultivators' fields for the States and Central Institutes

Bihar	West Bengal	Hyderabad	Pepsu	Travancore-Cochin	C.P.R.I.	Total
1,893	..	7	2	..	2	2,348
1,894	4	7	2	11	2	2,348
1,793	..	..	..	..	2	1,795
1	..	..	..	..	1	21
..	..	..	..	..	..	2
1	..	..	..	..	..	10
1,797	7	..	..	..	..	1,809
1	..	..	..	..	..	1
..	4	..	..	..	..	16
..	..	..	..	..	..	5
..	..	..	..	..	..	7
..	..	..	..	..	..	15
..	..	..	..	..	..	14
..	..	..	..	..	..	3
..	..	..	..	..	..	8
..	..	..	..	..	..	1
1,898	7	7	2	11	2	2,447

TABLE XVIII

Classification of experiments on cultivators' fields as randomised and not-randomised separately for replicated and unreplicated experiments

State/Central Institute	Replicated		Unreplicated		Total
	Randomised	Not-randomised	Randomised	Not-randomised	
States—					
Uttar Pradesh	40	..	..	321	361
Punjab	29	..	52	..	81
Madras	4	..	74	..	78
Bihar	6	..	98	1794	1,898
West Bengal	7	..	..	..	7
Hyderabad	..	..	..	7	7
Pepsu	2	..	..	..	2
Travancore-Cochin	1	10	..	..	11
C.P.R.I.	2	..	..	..	2
Total	91	10	224	2,122	2,447

Conclusions

From the above analysis three broad conclusions can be drawn. (i) It was observed that in some of the States the amount of experimentation done on various crops was disproportionate to the importance of the crops, while no experiments were conducted on some of the crops. It was found that this discrepancy was not due to lack of suitably located experimental stations. In view of these results it seems desirable to redistribute the experiments more equitably on the basis of the acreage and the importance of the various crops in different states. (ii) In the majority of the experiments the treatments tested were either manures or cultural practices but not both. There is clearly a need for more comprehensive experiments designed to study the effects of manures as well as cultural practices simultaneously. (iii) It was found that as many as 10 per cent of the total number of experiments reported were a complete waste as no information of any scientific or practical value could be extracted from them, while another 3 per cent were such that more than half the information was lost due to the improper choice of treatments. Also the examination of the designs adopted has revealed defects of various types. In view of the limited resources at our disposal greater attention is called for in planning the experiments more efficiently.

Summary

A total number of 3,980 experiments were reported to be conducted in the States during the year 1952-53 providing the information asked for, out of which 1,533 experiments were conducted at the research stations while the remaining 2,447 were laid out on cultivators' fields. Out of the experiments conducted at the research stations 76 per cent were from the six States, Bombay, Madhya Pradesh, Bihar, Uttar Pradesh, Madras and Punjab, while 14 per cent were from thirteen States included in the report. Of the total number of experiments 10 per cent were conducted at the central institutes. About 29 per cent of the total number of experiments were financed by either I.C.A.R., or Commodity Committees. As expected, relatively more experiments were conducted on cash crops than on cereals. Wheat received more attention than *jowar* or *bajra* even though the area under these two crops was considerably greater than that on wheat. Between sugarcane and cotton more experimentation was done on sugarcane than cotton while the area under cotton was nearly three times that under sugarcane. There is either disproportionate amount of effort spent or no experimentation is being done on some of the crops in some of the States. This disproportionality cannot be explained by the lack of suitably located experimental stations.

Nearly 96 per cent of the total number of experiments reported were replicated, *i.e.*, having more than ten plots. In regard to the agronomic factors under trial it seems that the tendency was mostly to test the manures and cultural practices separately and not to study them simultaneously. It was observed that the interest was largely centred on chemical fertilizers such as nitrogen, phosphorus, potash, etc., these three being tested in 40 per cent, 26 per cent and 7 per cent respectively of the total number of experiments excluding mixed crops and rotations. The

scoring technique of analysis revealed that the information was secured mainly on nitrogen and phosphorus on almost all the crops, the former recording more information than the latter.

Of the total number of experiments reported 12 per cent gave no information on simple effects of treatments. Further, there was a loss of information up to 50 per cent in 10 per cent of the experiments. About 34 per cent of the experiments failed either to include more factors or were too small, that is, included only one or two factors, whereas a comprehensive factorial experiment involving all the factors having a bearing on the problem would have given relatively more information with the same number of plots. Testing of a few selected combinations of the treatment constituents or some fixed ratio of fertilizer mixtures was done in 17 per cent of the cases. A split-plot design was adopted in many cases when it was not quite appropriate, while testing of too many levels or extreme levels was also frequent.

A few States laid stress on conducting experiments in cultivators' fields. Bihar conducted 78 per cent and Uttar Pradesh 15 per cent of the total number of experiments reported (2,443). It was observed that almost all the experiments in Madras were sponsored by the Indian Council of Agricultural Research, whereas in Punjab and West Bengal the experiments were conducted mainly under Commodity Committee schemes. Nearly 94 per cent of the experiments reported were on cereals such as paddy and wheat while 5 per cent of the experiments were devoted to the sugarcane crop. It was found that the interest was centred mainly in testing different fertilizer elements such as nitrogen, phosphorus and potash which were tried in 96 per cent, 96 per cent and 73 per cent respectively of the total number of experiments. A large number of experiments, 1,809 in number, included mixed fertilizers. Further, potash was tested only in Bihar. Practically all, i.e., 98 per cent of the experiments reported were manurial while the remaining were designed to study the effects of different cultural practices. In these experiments also the information as revealed by scores was secured mainly on nitrogen and phosphorus through artificial fertilizers. It was observed that 87 per cent of the total number of experiments were not randomised.

Acknowledgement

The authors thank the Directors of Agriculture of different States and Directors of the Central Research Institutes for their interest and co-operation in this work. They are grateful to Drs. D. J. Finney and F. Yates, the two F.A.O. experts assigned to the Council under the Technical Assistance Programme for the initiation of this investigation and in particular to Dr. D. J. Finney for indicating initially the line of approach to the analysis of the data and actually handling a part of it and to Dr. V. G. Panse, Statistical Adviser, I.C.A.R., for his interest in this work.

Appendix I

Survey of Agronomic Research Programmes, 1952-53

1. State : 2. Crop :

3. Location(s) (If Experimental Station(s) or Farm(s), State names and where situated ; if on cultivators' fields, write "C.F." and state districts included) :

4. Purpose of experiment :

5. Is this part of I.C.A.R. or Commodity Committee Scheme ?

6. How many experiments of this type on this crop in this season ?

7. Basal manuring (*i.e.*, on all plots) :

8. Is whole experiment irrigated ?

9. Experimental treatments (give list and full description of each) :

10. Design : 11. No. of replicates :

12. Total No. of plots : 13. Net plot size (approximate):

14. Are treatments randomized (independent in each block) ?

15. Are all experiments of same type separately randomized ?

16. Is experiment to continue for more than one crop on the same plots ?

17. If so, (a) When it was started ? (b) When will it end ?

(c) What is rotation of crops ?

(d) Specify date and nature of any changes in treatments other than planned changes listed in (9) :

18. Name of officer completing record sheet :

Appendix II

Survey of Agronomic Research Programmes, 1952-53

Instructions for recording information about the experiments

This survey is to be restricted to field experiments wholly or partly concerned with questions of agronomic practices : rates, types and methods of fertilizer application ; methods of cultivation ; seed-rates and spacing ; irrigation schedules ; mixed crops ; rotations of crops ; and so on. Experiments concerned solely with comparison of varieties, with plant protection and with grazing and animal nutrition will be excluded, as also will plots grown for the Crop Weather Scheme. Varietal trials in which fertilizers or other agronomic factors are tested simultaneously, however, will be included ; all other doubtful cases should be included.

The survey is intended to cover all agricultural crops. For annual crops, it should include every experiment sown or planted between 1st April 1952 and 31st March 1953, and for fruit, nut, and other perennial crops every experiment on which a harvest will be recorded within this period.

In general, each experiment will require a separate form. However, when a number of experiments on one crop have the same set of treatments and the same design (except that treatments are in different orders on the fields), these may be put on one sheet ; the number of experiments of identical design on this crop should then be stated. For experiments at Experimental Stations and Research Farms, the official name of the Station or Farm and its District should be stated. For experiments on cultivators' fields (*e.g.*," Stewart " experiments, " Grow More Food " trials, other schemes of experiments such as the manurial trials in Bihar and Uttar Pradesh, and demonstration trials on two or more plots that are to be harvested as experiments), the letters " C.F." should be entered and followed by a list of the Districts in the State having these experiments.

Under " Basal manuring " should be listed the level of application of any manurial treatment (*e.g.*, compost, green manuring, sulphate of ammonia) applied uniformity to all plots. Item (9) should be completed with especial care by listing and describing fully all experimental treatments. If the treatments are manurial, the types of fertilizers, rates of application, methods and times of application and chemical composition (especially of organics) should be stated. If different agronomic practices (*e.g.*, irrigation schedules or spacing of plants) are under test, these should be described fully and quantitatively. For example, treatments for paddy might be :

" All combinations of :

(i) 0, 30, 60 lb. N per acre (sulphate of ammonia, 20 per cent N)

(ii) 0, 20, 40 lb. P_2O_5 per acre (superphosphate 16 per cent soluble P_2O_5)
(both at transplanting)

(iii) Absence and presence of green manuring (sunnhemp)

(iv) Light, moderate, or intensive irrigation."

For example, treatments in an experiment of the manuring of paddy might be :

1. No manure.
2. 30 lb. N (as sulphate of ammonia, 20 per cent N)
3. 60 lb. N
4. 20 lb. P_2O_5 (as superphosphate, 16 per cent soluble P_2O_5)
5. 20 lb. P_2O_5+30 lb. N
6. 20 lb. P_2O_5+60 lb. N

You should either enter these exactly as above, or, if you are familiar with descriptions of factorial experiments, as—

all combinations of :

(i) 0, 30, 60 lb. N (as sulphate of ammonia, 20 per cent N)

(ii) 0, 20 lb. P_2O_5 (as superphosphate, 16 per cent soluble P_2O_5).

If you use the second form, which is shorter and more convenient for many complicated experiments, make quite certain that all combinations are included. If you have any doubts, please use the first type of description. Item (10) should contain a formal description as " seven randomized blocks of six plots, 5×5 Latin square, $3\times3\times3$ confounded in blocks of nine, etc. In an experiment intended to continue for several years on the same site, some changes in treatment may be part of the schedule of experimental treatments ; for example certain plots might be manured only in alternate years. These changes should be explained under item (9), and item 17 (d) should contain only changes that were not part of the original design. The back of the form may be used to record additional (information, if any) believed to be important to the unde standing of the experiment (*e.g.*, reasons why particular treatments were chosen or particular changes made, reasons for abandoning an experiment).

If your instructions on the layout of experiments give all this information, you may prefer to send spare copies of these instead of copying particulars on to the printed forms. No request is made for field plans, but either exact plans or sketches of the arrangement of plots will be of interest whenever these can be sent without extra trouble.

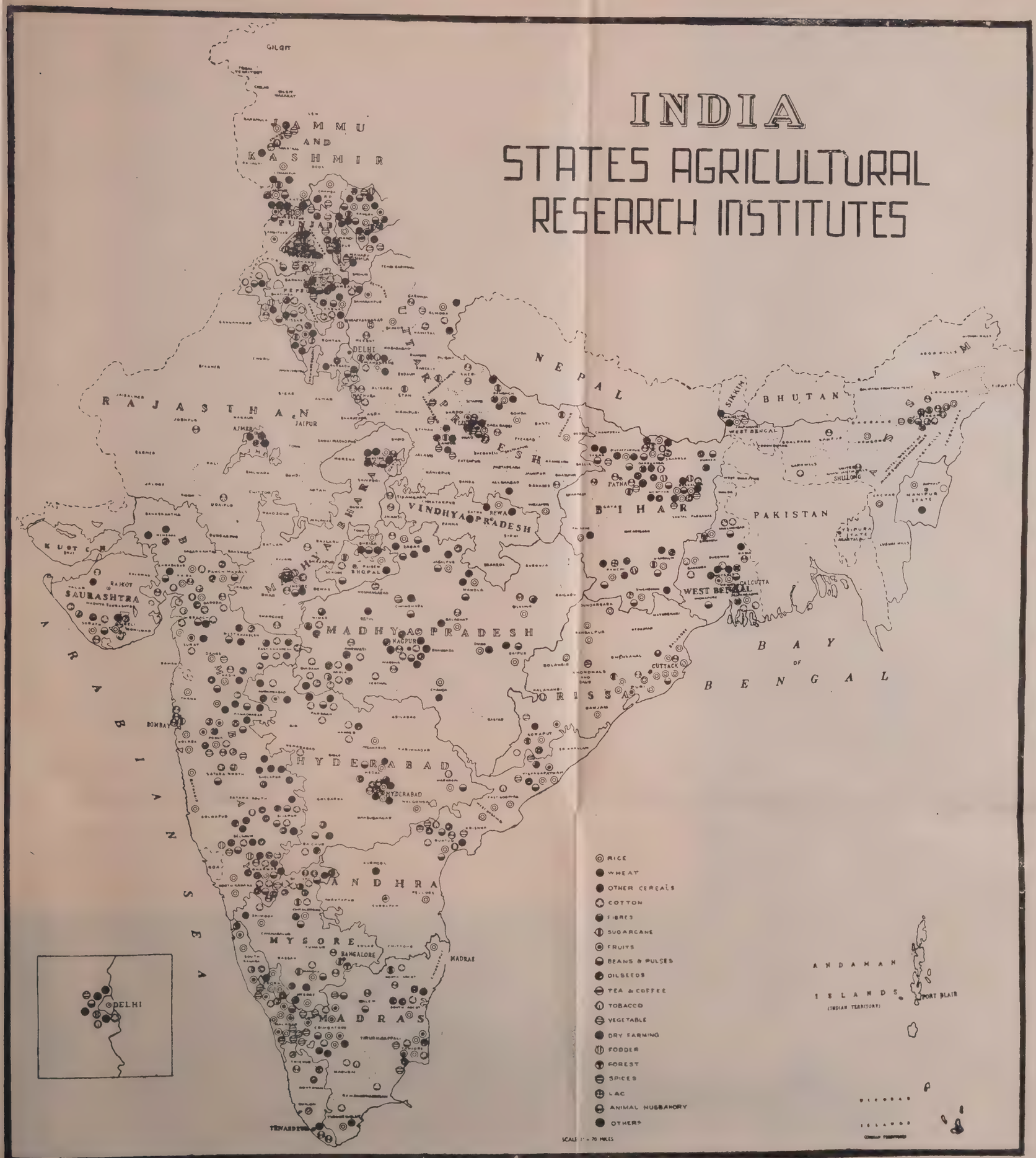

Fig. 1. Distribution of research stations in various States.

REVIEWS

YEAR BOOK OF AGRICULTURAL CO-OPERATION—1957

(Published by Basil Blackwell, Oxford. Price 30s net)

THE Year Book presents a valuable collection of material on the working of the co-operative movement in its various facets in different parts of the world. It provides interesting and useful material for the officials and non-officials engaged in the task of promoting the movement. The book will be read with interest by students, universities and other institutions interested in co-operation.

The book has several interesting features. The financial structure of co-operative societies is by far the most important. The societies in England for instance do not draw on two sources of capital as in some other countries (including India) viz., the public and governmental or other banks specially set up to foster co-operatives. The investment by members in their societies is also fairly high. In countries like Norway, the financial gap is filled through building up reserves for various purposes by sales co-operatives. The marketing fees have supplied the national co-operative with considerable funds to build storage facilities and the like. The Government also provided as an interim measure special funds to give grants-in-aid to agriculture through loans and grants to dairy-and-egg-marketing co-operatives. The Market and Credit Societies in Sudan supply agricultural implements, fertilizers and seeds and other farm requisites and provide timely finance from government and other sources and from members deposits and savings. In this 'backward area' increasingly greater importance is attached to thrift. In Ceylon where Co-operation has remained attached to the single purpose Society is now showing a healthy tendency towards spontaneous concentration of co-operatives and interlocking of diverse activities in the same region. In Phillippines finance and other aid is provided by the Agricultural Credit and Co-operative Financing Administration through a number of multi-purpose co-operative associations. The loans are given for crop production, for farm improvements, commodity facility and merchandising. In Japan Co-operatives not only carry on credit, marketing, purchasing and other businesses but they play a very substantial part to improve farmer-members' economy. In Western Samoa credit as a barrier to success is becoming less important. In Canada the degree of member ownership in co-operatives is increasing specially in the context of marketing and purchasing co-operatives. In Latin America the movement is mainly confined to the rural population. The co-operatives in most of these Latin American countries benefit through exemption from stamp duty, reduced customs duties and transport rates. The benefit of co-operation is recognised not only by governments but also by religious associations and trade union, etc. The Press also plays an important role. The experiences in Territories under U. K. Administration point to the fact that alongside expansion of credit there should be consolidation.

A separate chapter is devoted to India. The writer Margaret Digby has stated that the Indian Co-operative development programme is a " very ambitious one ". Similar views have been expressed by eminent authorities like Sir Malcolm Darling. But the whole context should be viewed from the economic and social point of view. The experiences in the European countries as well as other countries point to the fact that " Co-operation " provides an effective answer to the economic upliftment of ' man '. The movement should proceed on business lines, effective participation of members, education and training of personnel, linking of credit with marketing, processing storage and warehousing, etc. The Indian movement is an attempt to fill the past unfilled gaps and to provide such assistance as may be possible to make it stand on its own.

The book contains a good deal of material about large societies. In England, as in some other countries the size of the society and its character has largely contributed to its success. They provide for greater efficiency and wider variety of services. It is worth noting that in England there are societies which encompass several countries. The small societies have, no doubt advantages of their own. The most effective and successful instrument in developing co-operatives is in its form of organisation as a business organisation based on mutual service and for mutual benefit. There can be no doctrinaire approach in such matters. There is no reason to discount that both types of societies could not co-exist.

In regard to co-operative farming the book throws interesting light. In the West, stress is laid on mechanisation of agriculture. Pooling of small holdings and providing efficient service is recognised. The Polish experience has brought out that " collectivisation " does not provide the curative. In the U.S.S.R. efforts are made to make the collective farm system more workable and farmers are given greater autonomy. In the United States the co-operatives are given benefits which assist the farmer in having a better bargaining power in selling as well as in obtaining needed supplies and services. The experiences of other countries in Co-operative Farming will be of invaluable guide to India in evolving its own system.

The activities of co-operatives should be integrated and aligned with credit, marketing, storage, supply and should all go together. The experiences of the West conclusively go to prove that co-operation cannot develop in isolation and should *pari passu* proceed alongside development in other sectors of national economy. The book brings out clearly that through ' co-operation ' a nation can build itself to prosperity.

PADDY RICE PRODUCTION AND POTASH FERTILIZERS IN JAPAN

By Dr. W. Remy, Verlagsgesellschaft Fir Ackerbau MBH

(Published by Potash Fertilizers Limited, Bombay)

THIS small publication makes out a strong case for use of potassic fertilizers in rice production in Japan. The consumption of potassic fertilizers is rapidly increasing in Japan in recent years. There has been change of plant food ratio in favour of potash fertilizer in relation to nitrogen. The investigations conducted have shown that potash is required by the rice plant throughout its growing period. It is recognized, 'on soil in which potash is liable to be leached out and on deteriorated soils, it is necessary to apply it not only as a base fertilizer, but also as a top dressing'. The deficiency of potash adversely influences assimilation and respiration rate in leaves. The stem and leaf sheath are hardened with potash application by which susceptibility to lodging is reduced. Potash also favourably influences lignification of sclerenchyma. Under conditions of diffused light the yield reduction is less when plants are adequately supplied with potassium. In most of the fertilizer experiments conducted in India potash has been applied as dressing at sowing but in Japan its application is recommended 30 days before earing.

It has been established that leaves of rice varieties which are resistant to blast (*Piricularia oryzae*) exude more potassium and less NH_3, with a wide K/NH_3 ratio than the susceptible varieties. Therefore, application of nitrogen and porash together is recommended. Similarly, it is recognised that " Stiffle disease " or " root rot " of rice is a disease of potassium deficiency.

In the crop competitions, of which results have been compiled, the ratio of $N : P_2O_5 : K_2O$ is approximately 90 : 89 : 130 Kg/ha in applications of commercial fertilizers.

Finally recommendations have been given for fertilizer mixtures on highland, clay-loam, plain loamy soil, coastal area and sandy loam soil of Japan.

CROP PRODUCTION

By Harold D. Hughes, and Edwin R. Henson. Revised by Harold D. Hughes, Darrel S. Metcalf and Iver J. Johnson ; PP. 620 ; 1957 Macmillan Co., New York

THIS standard work on crop production has been reissued in a revised form. In the process of revision the text has been rewritten to a great extent and reorganised. In carrying out the revision results of modern researches on the subject and improvement in production practices have been kept in view. The information given covers a wide field relating to different phases of crop production.

Agronomic practices, including the management of the soil and irrigation water have been discussed in detail and the production of individual crops dealt with at length. In addition to grain and food crops, chapters have been devoted to what are known as cash crops as also forage pasture and fodder crops. The chapter on storage and marketing of grain will be deemed to be particularly useful in as much as there topic are not ordinarily included in books of this type. There is a special chapter explaining different technical terms relating to crop. References to important original sources of information are appended as foot notes at appropriate places. There is more or less an exhaustive index which will be of help in locating particular topics. The text is interspersed with a large number of illustrations and tabular data which help appreciation of the relevant discussion. The book in its present revised form will attract a wider circle of readers. It will undoubtedly be useful to the students of agriculture and also to the layman interested in crop production. The book is well printed and attractively bound.

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